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May 19, 2014

Final Technical Memorandum

Source Identification, Plume Delineation, Restoration Timeframe Estimation and Transition from Interim to Final Remedy

Newmark Groundwater Contamination Superfund Site
Source Operable Unit

San Bernardino, California

SOURCE IDENTIFICATION, PLUME DELINEATION, RESTORATION TIMEFRAME ESTIMATION AND TRANSITION FROM INTERIM TO FINAL REMEDY
NEWMARK GROUNDWATER CONTAMINATION SUPERFUND SITE

SOURCE OPERABLE UNIT
SAN BERNARDINO, CALIFORNIA

MAY 19, 2014

EXECUTIVE SUMMARY

Optimization Background

The U.S. Environmental Protection Agency's definition of optimization is as follows:

> *"Efforts at any phase of the removal or remedial response to identify and implement specific actions that improve the effectiveness and cost-efficiency of that phase. Such actions may also improve the remedy's protectiveness and long-term implementation which may facilitate progress towards site completion. To identify these opportunities, regions may use a systematic site review by a team of independent technical experts, apply techniques or principles from Green Remediation or Triad, or apply other approaches to identify opportunities for greater efficiency and effectiveness."* [1]

An optimization review considers the goals of the remedy, available site data, conceptual site model (CSM), remedy performance, protectiveness, cost-effectiveness and completion strategy. A strong interest in sustainability has also developed in the private sector and within federal, state and municipal governments. Consistent with this interest, optimization now routinely considers green remediation and environmental footprint reduction during optimization reviews. Optimization reviews may also include enhancing the CSM by performing 3-dimensional visualization and analysis (3DVA) of site data. An optimization review includes reviewing site documents, interviewing site stakeholders, potentially visiting the site for 1 day, and compiling a report or technical memorandum that includes recommendations in the following categories:

- Protectiveness
- Cost-effectiveness
- Technical improvement
- Site completion
- Environmental footprint reduction.

The recommendations are intended to help the site team identify opportunities for improvements in these areas. In many cases, further analysis of a recommendation, beyond that provided in this report, may be needed before the recommendation is implemented.

Site-Specific Background

The Newmark Groundwater Contamination Superfund (Newmark) site, located in San Bernardino, California, covers part of, the Bunker Hill Basin, an essential groundwater aquifer for the City of San Bernardino. More than 25 percent of the municipal water supply for San Bernardino's 175,000 residents has been affected by groundwater contamination associated with the site. The City of Riverside, with a population of approximately 250,000, relies on wells downgradient from the site for approximately 75

[1] U.S. Environmental Protection Agency. 2012 Memorandum: Transmittal of the National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion. From: James E. Woolford, Director Office of Superfund Remediation and Technology Innovation. To: Superfund National Policy Managers (Regions 1 – 10). Office of Solid Waste and Emergency Response (OSWER) 9200.3-75. September 28, 2012.

percent of its total water supply. More than 115,000 people in the rapidly growing communities of Colton, Loma Linda, Fontana, Rialto and several unincorporated areas, also use well water from the basin.

In 1980, volatile organic compound (VOC) contaminants, primarily tetrachloroethene (PCE) and trichloroethene (TCE), were identified at concentrations exceeding federal drinking water standards in eight municipal wells. Further investigation resulted in the closure of 20 water supply wells, 12 of which were put back into service after the implementation of treatment systems. The site was listed on the National Priorities List in 1989.

In 1990, the EPA initiated a remedial investigation/feasibility study (RI/FS) of a portion of San Bernardino known as the Newmark plume area. Based on RI/FS results, an interim remedial action (IRA) pump and treat (P&T) remedy was installed in 1998 with one set of extraction wells installed at the downgradient plume front and a second set of extraction wells installed at a mid-plume location to restrict continued downgradient migration. In 1992, EPA began investigation of a second area, known as the Muscoy plume. Based on RI/FS results, an interim P&T remedy was installed in 2005 at this plume's leading edge. Groundwater data generated during the original Newmark and Muscoy plume investigations led investigators to believe that that both plumes originated from a light industrial/commercial area located northwest of a local topographic high formed by a large bedrock outcropping (known as Shandin Hills).

In 1993, EPA designated the Newmark and Muscoy plume areas as the Newmark and Muscoy operable units (OUs), and defined an area encompassing both OUs as the Source OU. The Source OU, which is the focus of this technical memorandum, was designated to find the sources of the Newmark and Muscoy plumes. Several source investigations have been conducted to date within the Northwest (NW) Source Area, located northwest of Shandin Hills, and in the vicinity of the former San Bernardino Airport, located east of Shandin Hills (See Figure 1.1).

The 3DVA team was initially tasked with using 3-dimensional visualization and analysis (3DVA) to develop a preliminary CSM (PCSM) in support of Triad Approach systematic project planning of an RI for the Source OU. The focus of the RI was to identify potential sources µout the OU. The objective of this 3DVA effort was to use 3DVA geostatistical approaches to answer the following key technical questions in support of PCSM development:

1. Is there evidence of ongoing sourcing from the Northwest (NW) Source Area?

2. Is it possible for NW Source locations to be sole source of Newmark and Muscoy plumes?

3. Are Newmark/Muscoy plume distribution and mass:
    - Increasing / decreasing / not changing with time and installation of treatment systems?

4. Determine if time to achieve restoration using the present treatment systems is reasonable without system modification or additional monitoring points.
    - If not, what can be done to ensure restoration within a reasonable time frame?

As a function of the Source OU comprising the footprints of both the Newmark and Muscoy OUs, all of the data generated during the RI and IRA efforts undertaken for the Newmark and Muscoy OUs were determined to be directly applicable to the Source OU. Through the 3DVA effort, it became evident that these existing data are adequate to characterize the Source OU; thus, additional RI field investigation efforts are not warranted. Therefore, the PCSM is now considered the remedy-stage CSM (EPA 2011) for the site, which provides the basis for evolving the remedial action objectives (RAO) from containment to restoration in support of a site-wide Final Record of Decision (ROD).

Key Findings and Conclusions

Key findings and conclusions resulting from performing 3DVA for the Source OU include:

- An evaluation of existing site data revealed that Source OU conditions are such that further RI activities above and beyond the monitoring programs currently in place are not needed for EPA decision making purposes. A data-supported basis exists for evolving the remedial action objectives (RAO) from containment to restoration in support of the completing a Final Record of Decision (ROD).

- Groundwater contamination in the Source OU consists of a large (23-square-mile) low-concentration PCE plume (most concentration values between 5 and 20 micrograms per liter [µg/L]).

- Existing data indicate no active sources that would result in an increase in the concentration or size of the present Muscoy/Newmark plumes and specifically no evidence of ongoing sourcing from the NW Source Area. Groundwater from one monitoring well (CJ-10) continues to have relatively consistent PCE concentrations that predominantly range between 30 and 50 µg/L. However, the overall mass of PCE contaminant from the NW Source Area has greatly diminished with time.

- Results of on-line database searches for potential source sites throughout the Source OU indicated that there are no other ongoing sources located within the Source OU.

- The Muscoy/Newmark plumes are one plume system sourced from the NW Source Area, in particular, the former Camp Ono/Cajon Landfill. The 3DVA effort identified that the plume from the NW Source Area bifurcates at the northern edge of Shandin Hills and forms the Muscoy plume to the southwest under high water level conditions or the Newmark plume to the northeast under low water level conditions. 3DVA analysis indicates that an undulating bedrock surface, extensive units of interfingered high and low relative hydraulic conductivity (K_R) alluvial lithologies and fluctuating water table elevations are responsible for the plume's bifurcation.

- The mass of the PCE plume is decreasing with time, resulting in a significant decrease in the potential for the NW Source Area plume to deliver mass to the Newmark/Muscoy plumes. This is evidenced by PCE at a concentration of 5 µg/L having a mass of 450 pounds in 1997 and subsequently decreasing to a mass of 19 pounds as of 2012. The combined Muscoy/Newmark PCE 5 µg/L isoconcentration level plume mass has decreased from approximately 4,500 pounds to 799 pounds in 6 years (2006-2012).

- Contaminant levels in groundwater do not pose unacceptable risk to human health as defined by Comprehensive Environmental Response, Compensation and Liability Act, as risk levels do not exceed 1E-04. Furthermore, while current concentrations in groundwater do not meet state or federal drinking water standards (a maximum contaminant level of 5 µg/L) throughout the plumes, groundwater is treated before it is distributed for public consumption and use.

- The existing interim remedies appear to be effective in containment and restoration of the plume and are adequate for reaching site remedial goals within the estimates of time to achieve restoration for each treatment system area. Estimated times to achieve restoration for the contamination captured by the three treatment facilities for PCE in groundwater at or above 5 µg/L are: 19th Street North - 4 years; Newmark - 17 years; Waterman - 9 years. Estimations were derived using mass results from the 3DVA for each treatment area (Newmark, 19th Street North, and Waterman) combined with historical monthly PCE removal data from the three interim treatment systems.

- Under criteria for remedy protectiveness established by EPA in line with requirements of the Government Performance and Results Act (GPRA), the constructed status of the remedies and the existence of institutional controls (IC) support transition of the current remedies from interim to final in support of developing a Final ROD.

Recommendations

The results of 3DVA were used as the basis for recommendations to improve future remedy effectiveness (protectiveness), provide technical improvement and assist with accelerating site completion. Specific recommendations for cost reduction and for environmental footprint reduction (green remediation) were not a primary focus for this effort.

Improving remedy effectiveness

To improve future remedy effectiveness, the 3DVA team recommends using the results of the 3DVA effort to:

- Achieve consensus on completeness of site characterization, enabling the project to shift from an RI focus to a focus on transitioning the existing remedies from interim to final in support of developing a Final ROD.
- Support improvements in remedy effectiveness through optimization of the groundwater extraction wells and networks for the three treatment systems, resulting in more efficient targeting of contaminant removal.

Future use of 3DVA as the means for evaluating long-term monitoring (LTM) data would support:

- Maintaining a comprehensive, real-time understanding of remedy effectiveness and progress
- Determining and documenting when the site has achieved restoration goals

Cost effectiveness

Transitioning the currently operating interim remedies to final remedies will provide a number of cost benefits, primarily in the form of future cost avoidance through minimal to no additional RI field work, FS alternatives analysis, remedial design, remedial construction and LTM effort. Additional costs savings would be anticipated through optimizing the performance of the extraction well networks and potentially reduced operations and maintenance (O&M) requirements.

Technical improvement

To help identify opportunities for technical improvement, the 3DVA team recommends using the results of the 3DVA effort to:

- Focus any additional characterization on that which will assist the project team with optimization of existing remedies or support ROD contingencies.

- Support optimization of the groundwater extraction well network to provide a more detailed understanding of plume extent, plume morphology, migration pathways and behavior.

- Represent the treatment system capture zone analyses to the full plume distribution (horizontal and vertical) across the aquifer.
- Evaluate future concentrations of PCE at monitoring well CJ-10 to ensure no statistically significant increases in concentration.

- Evaluate if mass changes predicted for treatment areas are being met. If not, modify the time to achieve restoration estimate calculations.

Site Completion

To help achieve site completion, the 3DVA team recommends using the results of the 3DVA effort to construct capture zone analyses for treatment areas that encapsulate the entire aquifer for refining of current time to achieve restoration estimates.

Future use of 3DVA would support:

- Optimizing existing remedy performance to help achieve conditions for restoration.
- Using LTM data to maintain a comprehensive, real-time understanding of remedy effectiveness and progress.
- Applying visual and geostatistical analyses to demonstrate that the site has achieved restoration goals.

Additional recommendations for helping to achieve site completion include:

- Interim RAOs for the existing treatment systems should be modified to final RAOs to reflect a change from containment to restoration.

Environmental footprint reduction (green remediation)

No specific recommendations have been provided in this category; however, through applying the above recommendations reduction of the environmental footprint for will occur. Using 3DVA to understand and monitor clean up progress will accomplish reduced energy consumption, reduced air emissions, conservation of water resources, reduced impact to land and natural resources, and reduced material needs and waste generation by minimizing travel and the need for field investigation and the construction of additional site infrastructure.

NOTICE AND DISCLAIMER

Work described herein, including preparation of this report, was performed by Tetra Tech for the U.S. Environmental Protection Agency under Work Assignment 2-46 of EPA contract EP-W-07-078 with Tetra Tech. The report was approved for release as an EPA document, following the Agency's administrative and expert review process.

This optimization review is an independent study funded by the EPA that focuses on protectiveness, cost-effectiveness, site completion, technical improvements and green remediation. Detailed consideration of EPA policy was not part of the scope of work for this review. This report does not impose legally binding requirements, confer legal rights, impose legal obligations, implement any statutory or regulatory provisions, or change or substitute for any statutory or regulatory provisions. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Recommendations are based on an independent evaluation of existing site information, represent the technical views of the optimization review team and are intended to help the site team identify opportunities for improvements in the current site remediation strategy. These recommendations do not constitute requirements for future action; rather, they are provided for consideration by the EPA Region and other site stakeholders.

While certain recommendations may provide specific details to consider during implementation, these recommendations are not meant to supersede other, more comprehensive, planning documents such as work plans, sampling plans and quality assurance project plans (QAPP); nor are they intended to override applicable or relevant and appropriate requirements (ARARs). Further analysis of recommendations, including review of EPA policy may be needed prior to implementation.

PREFACE

This report was prepared as part of a national strategy to expand Superfund optimization from remedial investigation to site completion implemented by the EPA Office of Superfund Remediation and Technology Innovation (OSRTI). The project contacts are as follows:

Organization	Key Contact	Contact Information
EPA OSRTI	Steve Dyment	EPA Technology Integration and Information Branch 1200 Pennsylvania Avenue, N.W. Washington, DC 20460 dyment.stephen@epa.gov phone: (703) 603-9903
Tetra Tech, Inc. (Contractor to EPA)	Jody Edwards, P.G.	Tetra Tech 45610 Woodland Road, Suite 400 Sterling, VA 20166 jody.edwards@tetratech.com phone: (802) 288-9485
Sundance Environmental and Energy Specialists, Ltd. (Contractor to Tetra Tech)	Jacqueline C. Burton, Ph.D.	Sundance Environmental and Energy Specialists, Ltd. P.O. Box 33185 Santa Fe, NM 87594 jcburton@sundanceenvironmental.com phone: (505) 989-1951

LIST OF ACRONYMS AND ABBREVIATIONS

°F	Degrees Fahrenheit
µg/L	Micrograms Per Liter
3DVA	Three-Dimensional Visualization and Analysis
4DIM	4-Dimensional Interactive Model Player
ARAR	Applicable or Relevant and Appropriate Requirements
Bgs	Below Ground Surface
BP	Bladder Pump
CAS	Chemical Abstracts Service
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Contaminant of Concern
COPC	Contaminant of Potential Concern
CSM	Conceptual Site Model
cis-1,2-DCE	Cis-1,2-Dichloroethene
DTSC	California Department of Toxic Substances Control
EDR	Environmental Data Resources
ESD	Explanation of Significant Differences
FIPS	Federal Information Processing Standards
FS	Feasibility Study
Freon-11	Trichlorofluoromethane
Freon-12	Dichlorodifluoromethane
GAC	Granular Activated Carbon
GIS	Geographic Information System
GPRA	Government Performance and Results Act
HQ	Headquarters
IC	Institutional Control
IGCMP	Institutional Controls Groundwater Management Program
IRA	Interim Remedial Action
ITSI	ITSI Gilbane Environmental Services
K	Hydraulic Conductivity
K_R	Relative Hydraulic Conductivity
LTM	Long-Term Monitoring
MAROS	Monitoring and Remediation Optimization System
MCL	Maximum Contaminant Level
mph	Miles Per Hour
MSL	Mean Sea Level
MVS	Mining Visualization System
MWH	Montgomery Watson Harza
NAD	North American Datum
NCP	National Contingency Plan
NDDB	California Natural Diversity Data Base
NGFM	Newmark Groundwater Flow Model
NW	Northwest
O&F	Operational and Functional
O&M	Operations and maintenance
OSRTI	EPA's Office of Superfund Remediation and Technology Innovation

OU	Operable Unit
P&T	Pump and Treat
PCE	Tetrachloroethene or Perchloroethylene
PCOR	Preliminary Close-Out Report
PCSM	Preliminary Conceptual Site Model
PDB	Passive Diffusion Bag
ppb	Parts Per Billion
psi	Pounds Per Square Inch
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAC	Remedial Action Contractor
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objective
RI	Remedial Investigation
ROD	Record of Decision
RPM	Remedial Project Manager
RWQCB	Regional Water Quality Control Board
SBMWD	City of San Bernardino Municipal Water Department
SBVMWD	San Bernardino Valley Municipal Water District
SCAQMD	South Coast Air Quality Management District
SGSL	Soil gas screening level
SPP	Systematic Project Planning
TCE	Trichloroethene
TCF	Time Control Files
TIFSD	Technology Information and Field Services Division
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
VI	Vapor Intrusion
VOC	Volatile Organic Compound
WHS	Well Head Spigot

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1.0 INTRODUCTION

This technical memorandum presents the findings of a conceptual site model (CSM) development effort for the Newmark Groundwater Contamination Superfund (Newmark) site, located in San Bernardino, California (Figure 1.1). This effort included (1) synthesizing the findings and conclusions of prior investigations and interim remedial actions (IRA) performed from the 1980s to date, and (2) developing a comprehensive preliminary CSM (PCSM) for systematic project planning using 3-dimensional visualization and analysis (3DVA) methods and technologies.

The site is composed of three operable units (OU); the Newmark, Muscoy and Source OUs (Figure 1.2). The Source OU, which encompasses both the Newmark and Muscoy OUs, was designated to focus on finding the source or sources of the Newmark and Muscoy plumes.

Because the Source OU comprises the footprints of both the Newmark and Muscoy OUs, all of the data generated during the remedial investigation (RI) and IRA efforts undertaken for the Newmark and Muscoy OUs (as outlined below) are directly applicable to the Source OU. Through the 3DVA effort, it became evident that existing data are adequate to characterize the Source OU; thus, additional RI field investigation efforts are not warranted. Therefore, the PCSM is now considered the remedy-stage CSM (EPA 2011) for the site, which provides the basis for evolving the remedial action objectives (RAO) from containment to restoration in support of a site-wide Final Record of Decision (ROD).

1.1 PURPOSE

The purposes of this memorandum are to (1) document the 3DVA effort, (2) provide information that supports the transition of the current interim remedies to final remedies, and (3) support development of a Final ROD for the site (currently scheduled for September 2014).

The premise for interim to final remedy transition is that additional RI efforts are not expected to provide any new or significant information that would substantively change the currently active interim remedies. Therefore, it is recommended that project RAOs be evolved from containment to restoration, as supported by 3DVA team findings (using 3DVA), including:

- Low residual source mass and plume concentrations remain at the site.
- Insignificant to no risk to receptors remains based on current site status.
- Protections provided by operating interim remedies and institutional controls (IC) offer protectiveness for current and future planned land uses.
- Low estimated time to achieve restoration.

Furthermore, the site's status under criteria for remedy protectiveness established by the U.S. Environmental Protection Agency in line with the requirements of the Government Performance and Results Act (GPRA) support development of a Final ROD, as follows:

- Final Site Assessment Decision - Yes (06/24/1988).
- Human Exposure Under Control - Under current conditions at this site, potential or actual human exposures are under control.
- Contaminated Ground Water Migration Under Control - Contaminated groundwater migration at this site is under control.
- Construction Complete – Currently "No;" however, the basis exists for a change to "Yes."

- Site-Wide Ready for Anticipated Use – Currently "No;" however, the basis exists for a change to "Yes."

If the current interim remedies are acceptable as permanent remedies, the Construction Complete criterion would be met. As no other remedial activities are planned, and the remedy is protective for the current and anticipated uses in an urban area, the Site-Wide Ready for Anticipated Use criterion would be met.

The remainder of this memorandum provides the technical findings and provides rationale to support the determination that site conditions do not require additional RI and feasibility study (FS) efforts to support remedy decisions and transitioning.

1.2 PROJECT BACKGROUND

In 2010, EPA Region 9 requested technical support from the EPA's Office of Superfund Remediation and Technology Innovation (OSRTI) Technology Innovation and Field Services Division (TIFSD) to develop a PCSM in support of systematic project planning (SPP) for a Triad Approach-based RI of the Source OU at the site. Technical support has been provided by Tetra Tech, OSRTI's environmental mission support contractor and its subcontractor, Sundance Environmental & Energy Specialists LLC (Sundance), specialists in geostatistical 3DVA.

Technical support activities for this 3DVA effort have included:

- Refining project objectives and key technical questions to be answered for this project.
- Acquiring site documentation and data sets from 30 years of environmental work at the site.
- Evaluating and determining which documents and data sets (from the extensive 30 years of information) could provide the geologic, hydrogeologic and chemical analytical data necessary to support geostatistical 3DVA.
- Performing on-line database searches to identify any potential source sites throughout the Source OU.
- Performing geostatistical 3DVA to answer key technical questions and to pursue additional lines of inquiry as directed.
- Developing findings, conclusions and recommendations for the PCSM.
- Developing and delivering interim technical presentations to various stakeholders, including:
    - TIFSD and Region 9 Remedial Project Managers (RPMs)
    - Region 9 Branch Management
    - California Department of Toxic Substances Control (DTSC)
    - Santa Ana Regional Water Quality Control Board (RWQCB)
    - City of San Bernardino Municipal Water Department (SBMWD)
    - City of Riverside
    - East Valley Water District
    - Newmark Groundwater Flow Model (NGFM) Modeling Team
- Developing this technical memorandum.

At the beginning of the 3DVA effort, the main project objective was to develop a PCSM in support of SPP for an RI to be conducted for the Source OU. No specific RI scope or work plan for the Source OU RI had begun being prepared at the time the 3DVA effort was initiated; however, the 3DVA team was informed that the Source OU RI would apply a Triad Approach for field investigation and technology selection.

1.3 Site Stakeholder Organizations and Personnel

Site stakeholders include the following federal, state and municipal agencies:

Stakeholder Agency	Representative	Role	Contact Information
EPA Region 9	Mariam Fawaz	Regional Project Manager (RPM)	fawaz.mariam@epa.gov Phone: (415) 972-3078
EPA Region 9	Zi Zi Searles	Former RPM	searles.zizi@epa.gov Phone: 415-972-3178
EPA Region 9	Kim Hoang	Former RPM	hoang.kim@epa.gov Phone: 415-972-3147
EPA OSRTI	Stephen Dyment	HQ Optimization Lead	dyment.stephen@epa.gov Phone: 703-603-9903
California DTSC	Stephen Niou	State Lead	sniou@dtsc.ca.gov Phone: 714-484-5458
City of Riverside	Kevin Milligan	Assistant General Manager – Water for Public Utilities	kmilligan@riverside.ca.gov Phone: 951-826-5780
City of Riverside	Max Rasouli	Principal Water Engineer	mrasouli@riverside.ca.gov Phone: 951-826-5574
East Valley Water District	Ron Buchwald	District Engineer	rbuchwald@eastvalley.org Phone: 909-888-8986
SBMWD	Matt Litchfield	Director, Water Utility	Litchfield_ma@sbcity.org Phone: 909-384-5107
SBMWD	Stacey Aldstadt	General Manager	Aldstadt_st@sbcity.org Phone: 909-384-5091
SBMWD	Robin Ohama	Deputy General Manager	Ohama_ro@sbcity.org Phone: 909-384-7210
SBVMWD	Wen Huang	Principal Engineer	wenh@sbvmwd.com Phone: 909-387-9223
RWQCB	Kamron Saremi	Associate Water Resources Control Engineer	ksaremi@waterboard.ca.gov Phone: 951-782-4303

DTSC = California Department of Toxic Substances Control
HQ = Headquarters
SBMWD = City of San Bernardino Municipal Water Department
SBVMWD = San Bernardino Valley Municipal Water District
RWQCB = Santa Ana Regional Water Quality Control Board

1.4 3DVA Team

The 3DVA team consisted of the following representatives from OSRTI, Tetra Tech and Sundance:

Organization	Representative	Role	Contact Information
OSRTI	Stephen Dyment	HQ Optimization Lead	dyment.stephen@epa.gov Phone: 703-603-9903
Tetra Tech	Jody Edwards	Work Assignment Manager	jody.edwards@tetratech.com Phone: 802-288-9485
Tetra Tech	Mark Shupe	Hydrogeology Support	mark.shupe@tetratech.com Phone: 703-885-5516
Tetra Tech	Michelle Nolte	Engineering Support	michelle.nolte@tetratech.com Phone: 408.979.9451

Organization	Representative	Role	Contact Information
Tetra Tech	Eric Morton	Risk Assessment Support	eric.morton@tetratech.com Phone: 312-201-7797
Sundance	Jackie Burton, PhD President	3DVA Services	jcburton@sundanceenvironmental.com Phone: 505-989-1951
Sundance	John Shafer, PhD	3DVA Services	jshafer@sundanceenvironmental.com Phone: 505-470-2663
Sundance	Frank Hagar, P.G.	3DVA Services	fhagar@sundanceenvironmental.com Phone: 505-470-5731
Sundance	Duke Brantley, M.S.	3DVA Services	dbrantley@sundanceenvironmental.com Phone: 505-470-3253

1.5 SITE HISTORY AND BACKGROUND

The Newmark Groundwater Contamination Superfund site, located in San Bernardino, California, covers part of an essential groundwater aquifer for the City of San Bernardino. More than 25 percent of the municipal water supply for San Bernardino's 175,000 residents has been affected by the groundwater contamination associated with the site. The City of Riverside, with a population of approximately 250,000, relies on wells downgradient from the site for approximately 75 percent of its total water supply. More than 115,000 people in the rapidly growing communities of Colton, Loma Linda, Fontana, Rialto, and several unincorporated areas also use well water from the basin.

In 1980, volatile organic compound (VOC) contaminants, primarily tetrachloroethene (PCE) and trichloroethene (TCE), were identified in groundwater at concentrations exceeding federal drinking water standards in eight municipal wells located in San Bernardino during a state water quality monitoring event. Additional VOCs identified in the associated groundwater contamination plumes included trichlorofluoromethane (Freon-11) and dichlorodifluoromethane (Freon-12). Further investigation resulted in closure of 20 water supply wells within a 6-mile radius of the site, 12 of which were put back into service after air stripping towers had been installed on eight wells and carbon filtration had been installed on four wells. The site was listed on the National Priorities List in 1989 (EPA 1995).

In 1990, the EPA initiated an RI/FS of a portion of San Bernardino located east of a local topographic high formed by a large bedrock outcropping (known as Shandin Hills); this area became known as the Newmark plume area (Figure 1.3). Based on RI/FS results, an interim pump and treat (P&T) remedy was installed in 1998, with one set of extraction wells installed at the downgradient plume front and a second set of extraction wells installed at a mid-plume location to restrict continued downgradient migration (EPA 2008) (Figure 1.4).

In 1992, EPA began an RI/FS of a second area, known as the Muscoy plume (Figure 1.3). Based on the RI/FS results, an interim P&T remedy was installed in 2005 at the plume's leading edge (Figure 1.4) (EPA 2008). Groundwater data generated during the original Newmark and Muscoy plume investigations led investigators to believe that that both plumes originated from a light industrial/commercial area located west of Shandin Hills (EPA 1993).

In 1993, EPA designated the Newmark and Muscoy plume areas as the Newmark and Muscoy OUs, and defined an area encompassing both OUs as the Source OU (Figure 1.3). The Source OU, which is the focus of this technical memorandum, was designated to find the sources of the Newmark and Muscoy plumes. Several source investigations have been conducted to date within the Northwest (NW) Source Area, located northwest of Shandin Hills, and in the vicinity of the former San Bernardino Airport, located east of Shandin Hills (EPA 1995).

ICs are in place to ensure protectiveness at the site is maintained during operation of the remedies, including a city ordinance that requires a new permit for any new, non-municipal well or a change in existing well pumping conditions. An Institutional Controls Groundwater Management Program (IGCMP) for municipal wells requires consultation with the municipal water district to confirm mutual impacts to the basin's groundwater balance for any new wells. Basin groundwater use is supported by the NGFM, which is maintained by the city and its specialty modeling consultants.

A Final ROD for the site is scheduled to be issued in September 2014. Per prior agreements, the city has taken over responsibility for operations and maintenance (O&M) of the remedy and will retain responsibility after the Final ROD has been issued.

1.5.1 DESCRIPTION OF THE SOURCE OU

The Source OU encompasses the Newmark and Muscoy OUs and includes an area of approximately 23 square miles that is bounded to the east/northeast by the San Andreas Fault and the San Bernardino Mountains, to the west/southwest by the Loma Linda fault and Lytle Creek, to the south by a boundary approximated by 7th Avenue in downtown San Bernardino, and to the East by East Twin Creek.

The NW Source Area occupies approximately the northwestern third of the Source OU (Figure 1.2) and is located northwest of a bedrock outcrop known as Shandin Hills. The Source OU was designated as the framework for identifying potential sources of the Newmark and Muscoy plumes (EPA 1995).

1.5.2 GENERAL SITE HISTORY WITHIN THE SOURCE OU

The Source OU lies primarily within the city limits of San Bernardino. Land use in the City of San Bernardino includes the California State University on the northern portion of the city, residential properties including single and multi-family dwellings, commercial establishments, light industrial facilities, heavy industrial facilities, public facilities, open space and golf courses. While the majority of residences are located in the downtown area, recent population increases have expanded development across the area. Commercial and industrial land use predominantly occurs south of the downtown area (EPA 1993).

Groundwater is a major source of drinking water for the City of San Bernardino, the City of Riverside, and surrounding communities. According to the Muscoy OU ROD, issued in 1995, approximately 500,000 residents depend on this drinking water resource. Twenty-five percent of the municipal water supply had been affected by the Muscoy and Newmark OU plumes (EPA 1995).

Since the discovery and characterization of the Newmark and Muscoy OU VOC plumes, several investigations have been conducted to identify facilities that either used or possibly used the original contaminants of potential concern (COPC) (PCE, TCE, Freon-11 and Freon-12) in the Newmark and Muscoy OUs that potentially have been sites of the release of these constituents to groundwater. Locations of the primary potential source sites investigated are provided on Figure 1.5. In particular, past investigations identified the following primary suspected sites where plume constituents may have been released to groundwater:

Camp Ono: Also known as the San Bernardino Engineering Depot, Camp Ono was a World War II-era facility operated by the U.S. Army to provide supplies to Japanese internment camps and training camps located within California. The 1,770-acre facility operated from 1941 to 1947 and included a laundry, a wastewater treatment plant, motor pool areas, an equipment refurbishment area, an oil change ramp, wash racks and a locomotive/tractor servicing area (EMCON, 1995).

Cajon Landfill: The Cajon Landfill is an inactive Class II/III landfill with an area of approximately 127 acres. The landfill consists of two unlined waste disposal cells of approximately equal size separated by a railroad easement. Each cell was constructed by excavating a pit (below grade), filling the pit with refuse, and covering the pit with excavated material from other areas (SAIC 2001). The finished height of the two cells ranges from 30 to 40 feet above the surrounding grade. The landfill was operated by the County of San Bernardino between 1963 and 1980. Wastes accepted included demolition, septic, sewage treatment wastes and asbestos. In addition, during a period in 1965, a "considerable amount" of petroleum distillate waste was placed in the landfill (SAIC 2001). At closure in 1980, the landfill was covered with a 3-foot layer of thick, silty sand. In response to the deterioration of this initial covering, an engineered cap was installed in 1998 (SAIC 2001).

San Bernardino Airport: This private airport, located east of Shandin Hills, operated from the late 1950s through the 1970s. An aerial photographic analysis conducted by EPA in 1990 indicated that a solvent disposal pit and several potential waste release areas were once located at the airport. Eyewitness accounts also indicated that waste releases had occurred. As part of the Newmark OU RI, some soil sampling was conducted at the airport where groundwater contamination had been identified. The soil sampling was conducted at the suspected location of a solvent disposal pit known as the "Cat Pit" and associated disposal trenches. Soil analytical results indicated that VOCs were present in soil, but no TCE or PCE was identified. Based on the results of the Newmark OU RI, the airport is no longer a suspected source of TCE or PCE to groundwater.

The Muscoy OU ROD (EPA 1995) removed Freon-11 and Freon-12 from the list of COPCs based on risk assessment results that concluded that these compounds at the site posed no increased risk to human health and the environment.

1.5.3 HISTORY OF REGULATORY ACTIONS, INVESTIGATIONS & REMEDIAL EFFORTS

The site has undergone a series of investigations and remedial actions from 1980 to present. Figure 1.6 provides a timeline of regulatory actions, investigations and remedial efforts at the site from 1980 to 2010. Tables 1.1 through 1.3 provide summary information for regulatory actions, investigations and remedial efforts.

2.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section presents the physical characteristics of the Source OU.

2.1 TOPOGRAPHY

The Source OU lies within the San Bernardino Valley, southeast of the San Gabriel Mountains and southwest of the San Bernardino Mountains (EPA 1994). Several local topographic highs are present with the Source OU, most notably Shandin Hills, located to the southeast (Figure 2.1). These topographic highs are bedrock outcroppings created by tectonic movements along the northwestward-trending San Jacinto fault, which bounds the basin to the east/northeast, and the San Andreas fault, which bounds the basin to the west/southwest.

From the northwestern corner of the Source OU, ground surface elevations decline from approximately 1,750 feet to approximately 1,050 feet mean sea level (MSL) along the southeastern boundary of the OU. The maximum elevation within the OU is 1,850 feet MSL at the summit of Shandin Hills (Stantec 2008).

Urban development within the Source OU has replaced much of the native habitat and landscape. Land use is discussed further in Section 2.6.

2.2 METEOROLOGY / CLIMATE

Climate in the City of San Bernardino is characterized by hot summers and mild winters. Temperatures range from 30 degrees Fahrenheit (°F) to the mid-60s°F in winter; and from the 50s °F to the upper 90s°F in summer (EPA 1993). The highest precipitation months are typically December through February. Between 1979 and 2004, average annual precipitation was 16.41 inches (GeoSciences 2009). Mean relative humidity averages approximately 57 percent (EPA 1993).

The average measured wind speed for the period from March 1998 to July 2013 in San Bernardino County is 5.2 miles per hour (mph), with wind direction generally trending to the southwest (Figure 2.2). The Santa Ana winds, which flow down from the Cajon Pass, appear intermittently during the fall and winter and can bring winds with velocities that exceed 60 mph (EPA 1993).

2.3 SURFACE WATER HYDROLOGY

The Source OU is located in an area of water-bearing alluvial fan-type deposits known as the Bunker Hill Groundwater Basin (Stantec 2009). Lytle Creek flows southeastward in a wide lowland known as the Cajon Wash, which borders the Source OU to the west. Southeastward-flowing Cable Creek occupies the lowland area west of Verdemont Hills, the northernmost promontory in a chain of bedrock hills extending northwestward from Shandin Hills. Approximately 0.5 miles south of Verdemont Hills, the Cable Creek Channel bends to the southwest to join Lytle Creek at a point approximately 2 miles west of Shandin Hills. Figure 2.3 shows these and other local hydrologic features.

Stream flow originates from mountainous regions located in proximity to the groundwater basin and is intermittent. During storms, stream flow exits the mountain canyons and enters the valley along its perimeter, where it then feeds the Santa Ana River, Mill Creek, Lytle Creek, and Cajon Creek, and moves across the alluvial fans. While some stream flow undergoes evaporation or is transpired through vegetation, records show that approximately 90 percent of the stream flow recharges the basin (EPA

1994). Additional groundwater recharge is provided by the California aqueduct system, which imports water from Northern California (EPA 1993).

2.4 REGIONAL GEOLOGY

Stantec Consulting Corporation (Stantec) and Geoscience Support Services, Inc. (Geoscience) have produced extensive reviews and documentation of the regional geology and hydrogeology while preparing the NGFM (Stantec 2008a; Geoscience 2009). EPA has been part of development of these materials, and the materials have been subjected to peer review. It was agreed that data obtained by Stantec and Geoscience provide the basis for the Newmark 3DVA effort to provide transparency and allow the use of the Mining Visualization System (MVS) results in the NGFM and vice versa.

Regional geology and hydrogeology for the site is well-documented and complex. Geology beneath the site is composed of two basic geologic units: unconsolidated sedimentary deposits and bedrock. The unconsolidated sedimentary deposits are water-bearing alluvium derived from the San Gabriel Mountains to the northwest and the San Bernardino Mountains to the northeast. Bedrock beneath the alluvium deposits is identified as the Pelona Schist. The alluvium is highly heterogeneous, made up of clay, silt, sand, and gravel (Figure 2.1). Erosion of the San Gabriel and San Bernardino mountains formed the confluent alluvial fans at the base of the mountains of the San Bernardino Valley. The thickness of alluvium within the San Bernardino Valley varies, increasing from 400 feet at the base of the San Bernardino Mountains to as much as 2,100 feet at the center of the valley in the vicinity of the Loma Linda and San Jacinto fault zone.

Several faults exist in the region, including the San Andreas and San Jacinto faults, which trend in the northwesterly direction, and the Loma Linda fault, which trends in the northwest/southeast direction (Figure 2.4) (Stantec 2008).

Although significant faulting exists in the basement bedrock, the overlying sediments show little if any expression of these faults within the boundaries of the Source OU. In addition, the only identified faults that could potentially affect groundwater flow are outside the Source OU boundaries. Faults, therefore, were not represented in the 3DVA of the Source OU. Within the Source OU boundary, this approach to handling faults is consistent with the lithologic interpretation used in development of the NGFM.

2.5 REGIONAL HYDROGEOLOGY

Groundwater and surface water issues within the study area are reportedly confined to the Bunker Hill groundwater basin. The San Bernardino Mountains to the northeast, the Crafton Hills and the Badlands to the south, and the San Jacinto fault to the southwest provide bounding to the basin. Increased rainfall in the period from 1963 through 1982 had contributed to significant recharge to the groundwater basin, resulting in higher natural stream flow and increased streambed percolation. Other factors that encouraged recharge in the area included water purveyors upgradient of the basin “recharging diverted natural stream flow and imported water from the California Aqueduct” (EPA 1993). Since 1986, however, recharge has decreased because of the drought (EPA 1994).

The aquifer at the Newmark site is found in the alluvium at the site and for the 3DVA has been assumed to behave as one aquifer system. The documented flow direction of the alluvial aquifer at the Newmark site is northwest to southeast (Figure 2.5) (Stantec 2008a).

2.6 DEMOGRAPHY AND LAND USE

Land uses within the Source OU are primarily industrial and commercial with some residential communities. Light industrial and commercial properties and the majority of residential properties are largely located within the Newmark and Muscoy OU areas (EPA 2008). The NW Source Area, which has been the focus of past source investigations, includes land uses such as a closed landfill (Cajon Landfill), a former World War II Army installation (Camp Ono), a railroad, commercial structures, and light and heavy industry.

2.7 ECOLOGY

According to ecological findings outlined in the RI/FS reports for the Muscoy OU (EPA 1994) and Newmark OU (EPA 1993), urban activities and past agricultural operations have modified much of the San Bernardino Valley. These land uses have removed much of the native vegetation that existed on the alluvial fans and floodplains of the valley. Remaining native vegetation in the site area includes chaparral, sage scrub and some riparian areas (EPA 1994). Primarily, vegetation consists of non-native landscape species. As a result of urbanization, the area supports a limited diversity of plant and animal life.

Sensitive plant communities have been identified within the floodplains in the vicinity of the Santa Ana River and associated tributaries. Habitats are composed of Riversidean alluvial fan sage scrub, some Riversidean sage scrub and herbaceous weed plants. Plants that are located outside of the flood zone include chaparral (EPA 1994).

Studies conducted during RI activities for the Newmark and Muscoy OUs identified habitat that supports endangered plant species. According to the Muscoy RI/FS report (EPA 1994), the California Natural Diversity Data Base (NDDB) “RareFind” identified the Riversidean alluvial fan scrub located near Lytle Creek and the Cajon Canyon as habitat suitable for the Santa Ana woollystar and the slender-horned spineflower. Both of these plant species are listed on federal and state endangered plant species lists. The NDDB indicated that the Santa Ana woollystar had been identified within the Muscoy OU; however, a survey conducted in 1991 did not locate this species. The slender-horned spineflower has not been identified on site, but a survey conducted in 1990 indicated that suitable habitat exists that could support its growth (EPA 1994).

According to the Newmark and Muscoy OU RODs, no significant impact to environmental receptors is expected since urbanization:

> “Given the present developed condition of the site and the major exposure pathway consideration of contaminated groundwater, there was no expectation for significant impact to potential environmental receptors. Urbanization has already replaced habitat potential; therefore, no significant number of receptors appeared to be present. There appeared to be no apparent mechanism for exposure to environmental receptors from contaminated groundwater. Also, there was no indication that future site plans would reinstate habitat and thereby recreate a potential for environmental receptors in the future” (EPA 1993; EPA 1995).

2.8 AFFECTED MEDIA

The primary affected medium at the site is groundwater, which is the primary source of potable water for the residents and businesses of San Bernardino County. Isolated areas of potentially contaminated soils may exist in the NW Source Area.

2.9 CONTAMINANTS OF CONCERN

The following COCs were identified within the Newmark and Muscoy OUs:

CAS #	Contaminant Name	Abbreviation	Operable Unit
75-34-3	1,1-Dichloroethane	1,1-DCE	Muscoy
79-01-6	Trichloroethene	TCE	Muscoy
127-18-4	Perchloroethylene Tetrachloroethene	PCE	Newmark Muscoy
156-59-2	cis-1,2-Dichloroethene	cis-1,2-DCE	Muscoy
156-60-5	1,2-trans-Dichloroethene	1,2-trans-DCE	Newmark
75-69-4	*Trichlorofluoromethane**	*Freon-11*	*Muscoy*
75-71-8	*Dichlorodifluoromethane**	*Freon-12*	*Muscoy*

Notes: CAS = Chemical Abstract Service.
*No longer listed as a COC. See Muscoy OU ROD

The Muscoy OU ROD (EPA 1995) removed Freon-11 and Freon-12 from the list of COCs because risk assessment efforts concluded that there was no increased risk to human health and the environment from these compounds at the site. Therefore, the primary COCs for this project and as pertains to the Final ROD were PCE and TCE.

3.0 PROJECT OBJECTIVES

The original objective of the 3DVA effort was to develop a PCSM of the Source OU to support Triad Approach SPP of anticipated RI activities to identify potential sources throughout the OU.

Specific technical objectives were to use 3DVA geostatistical approaches to answer the following key technical questions in support of PCSM development:

1. Is there evidence of ongoing sourcing from the NW Source Area?

2. Is it possible for NW Source locations to be sole source of Newmark and Muscoy plumes?

3. Are Newmark/Muscoy plume distribution and mass increasing, decreasing, or not changing with time and installation of treatment systems?

4. Determine if time to achieve restoration using the present treatment systems is reasonable without system modification or additional monitoring points. If not, what can be done to ensure restoration within a reasonable time frame?

As indicated in Section 1.0, through the 3DVA effort it became evident that existing data are adequate to characterize the Source OU; thus, additional RI field investigation efforts are not warranted. Therefore, the PCSM is now considered the remedy-stage CSM (EPA 2011) for the site and provides the basis for evolving the RAO from containment to restoration in support of a final site-wide ROD.

Additional objectives included providing information from the 3DVA effort to the NGFM, supporting site stakeholder meetings with project status update presentations, and supporting briefings to Region 9 and EPA HQ management personnel.

4.0 OVERVIEW OF 3DVA PROCESS

Figure 4.1 presents the 3DVA process and how elements of the process were combined to provide the 3DVA results presented in this technical memorandum. This section provides an overview of the 3DVA process. Sections 5.0 and 6.0 provide detailed descriptions of the process.

The 3DVA process began with confirmation and assessment of project objectives and discussions of key issues to address. During the 3DVA effort, various technical tasks were augmented or modified based on evolved site knowledge and inquiry interests while ensuring the primary project objectives were achieved.

The following fundamental activities of the 3DVA, as described in the indicated subsections, were completed once project objectives were established:

- Assimilation and evaluation of site data (Section 4.1)
- Development of a project geographic information system (GIS) (Section 4.2)
- Determination of geostatistical visualization parameters (Section 4.3)
- Quality control (Section 4.4)
- Development of component visualizations (Section 4.5)
- Integrated visualization and analysis (Section 4.6).

4.1 ASSIMILATION AND EVALUATION OF SITE DATA

3DVA efforts used existing site quantitative data (water levels, chemical analytical results, and lithology at set depth intervals) versus data interpretations or empirical data to document site features (lithology and hydrogeology and plume characteristics). The following site and environmental data were provided by the site team:

- Locational/geographic data (including site features)
- Geologic data
- Hydrogeologic data
- Groundwater contaminant chemistry data

Public sources of data, such as digital land surface elevation data or aerial maps, were used to supplement site-specific data.

Data were provided to the 3DVA team in electronic formats and hardcopy within the initial data turnover package described in Section 5. Electronic data were summarized in spreadsheets (MS Excel) and databases (MS Access and EQuIS). Other data were provided in the form of document files, such as MS Word, Adobe pdf and hardcopy reports, tables and memoranda.

A substantial quantity of diverse information was provided. Documents as well as various databases were reviewed and categorized for use in the project. The data for 3DVA were then evaluated to determine the types of visualizations that could be produced. Additional data were acquired as necessary where the provided data were not sufficient to meet the project objectives. For example, sampling methodologies used in historical site work were not identified in the analytical databases acquired from EPA Region 9. The methodologies and actual sampling intervals were located in a separate document and manually incorporated into the visualization project database for geostatistical analysis and visualization.

Detailed descriptions of site data assimilation and evaluation activities are presented in Section 5.0.

4.2 DATABASE DEVELOPMENT

The 3DVA effort required management of large sets of data to support creation of multiple visualization products spanning 15 years. Project data were organized in databases that could be manipulated to construct the electronic data files needed for the visualizations. Data entry development included the creation and maintenance of a project GIS. The project GIS was used in conjunction with the 3DVA software to manage spatial data. The project GIS facilitated the creation of 3DVA overlays, development of an understanding of spatial relationships of the project data, and construction of data files used in other elements of the 3DVA process.

Detailed descriptions of site database development activities are presented in Section 5.0.

4.3 DETERMINATION OF GEOSTATISTICAL VISUALIZATION PARAMETERS

Geostatistical visualization parameters were established and evaluated, an important element of the 3DVA process. Geostatistical analyses were based on a number of parameters that controlled how geostatistical estimations (variography and kriging) were performed. Critical geostatistical parameters established included:

- Grid resolution necessary to adequately display the visualized data
- Whether adaptive or proportional gridding was to be used
- Ratio of horizontal to vertical anisotropy
- Reach and maximum number of points included within the reach
- Whether the data were log10 transformed
- How groundwater contaminant concentrations were distributed along the vertical span of each well screen (max-gap)

Detailed descriptions of geostatistical visualization parameter development are presented in Section 6.0.

4.4 QUALITY CONTROL

Quality control (QC) was applied throughout the 3DVA process, from data assimilation and evaluation through final creation of the integrated site visualizations. Data quality and consistency were assessed to ensure their appropriate use in visualization and analysis. Specific quality review activities included:

- Data comparability and representativeness were reviewed. Comparability was assessed between the various sampling methods used and differences in analytical method reporting limits. No notable discontinuities or trends in the data sets were identified that appeared strictly laboratory- or method-related (that could not be explained by other factors such as pumping effects or hydrogeology). Reporting limits were fairly comparable and caused no significant effects in the overall trends in the data sets.
- Although there were limited analytical QC data in the database, including field blanks and duplicates, no significant issues were observed in the blanks that could have affected interpretations for the primary COCs. Duplicate sample agreement was sometimes poor and, based on the limited data available, it was difficult to determine why, but the concentrations were typically low. All analytical results were plotted for the trend evaluation, including the duplicates, so that full “scatter” of the data could be observed. They do not appear to have significantly

affected the overall evaluation (the long-term trends and overall variability that were observed in the data sets).

- An integral part of the data review and QC was choosing the years with the best and largest data sets for visualization. This choice involved review of well coverage maps over time, along with overall sample counts, method type and the trend plots.
- Strict analytical precision and accuracy were not evaluated given that laboratory QC information was not provided in the database, but was instead distributed throughout the hardcopy reports in varying detail. However, most data sets reviewed had been validated and most data sets appeared well-behaved and unaffected by analytical method QA issues. When notable discontinuities in the data sets were observed, they usually occurred across multiple wells, indicating broader trends in the data rather than a sample quality issue.
- Note: EPA has reason to question analytical data from one sampling event used to perform the 3DVA effort; the spring 2011 event in the NW source area. At this time EPA is not able to say that the data from that one sampling event are of known quality. However, all other data from the other sampling events summarized in this technical memorandum are of known quality and suitable for use in the 3DVA effort.

QC was also applied to the data management process to ensure that the data entry files matched the data as originally received. The project GIS was used to verify that all locational data used in the 3DVA were in the chosen geographic projection (for example, State Plane Coordinate System).

QC included verification of the geology, hydrogeology and groundwater contaminant chemistry component visualizations (Figure 4.1). Component visualizations were analyzed to evaluate how well they matched input data at known locations throughout the visualization domain. The visualizations were analyzed by expert geologists, hydrogeologists and chemists to confirm that the visualizations were valid reflections of existing data and the surface and subsurface environment of the site.

Additional information on QC activities is presented in Section 6.0.

4.5 DEVELOPMENT OF COMPONENT VISUALIZATIONS

Component visualizations were developed and used to create the integrated site visualizations. The following three individual "components" were visualized:

- Geology
- Hydrogeology
- Groundwater contaminant chemistry; specifically PCE.

Component visualizations were also used to optimize the 3DVA process. The data sets that described geology, hydrogeology and groundwater contaminant chemistry were vastly different in type of data, spatial density and distribution and number of discrete data points. Therefore, each of these data sets was geostatistically analyzed independently to determine the unique aspects of each component data set. Independent visualization of each component data set was used to ensure that no artificial bias was introduced into one component's analysis based on the analysis of another component's database.

Detailed descriptions of component visualizations development are presented in Section 6.5.

4.6 INTEGRATED VISUALIZATION AND ANALYSIS

Integrated visualizations, created by combining the component visualizations, were used to support all site analyses, such as comparison of visualized PCE plumes to geology and how the temporal changes in the water table affected migration of PCE. Integrating the component visualizations allowed for the calculation of PCE mass in the plume based on soil effective porosities. The independent component visualizations ensure that the correlations of physical features and contaminant properties seen in the integrated visualizations reflect site conditions and are not a result of computational artifacts.

Detailed descriptions of integrated visualization and analysis are presented in Section 7.0.

5.0 SITE DATA AND DATA COMPILATIONS FOR VISUALIZATION

Data used for 3DVA were provided by EPA Region 9, ITSI Gilbane Environmental Services (ITSI) (EPA Region 9's Remedial Action Contractor [RAC]), the City of San Bernardino, and Stantec (consultants for the City of Bernardino).

The majority of data were made available in electronic formats, particularly in MS Excel spreadsheets, MS Access databases and EQuIS database queries (in the form of MS Access databases). Some geologic and bedrock data elements were provided in derivative software products such as the Dynamic Graphic Inc.'s EarthVision viewer, while other data were provided in text formats via MS Word documents or Adobe pdf (for example, groundwater flow model information, site history, potential source analyses and sampling protocols). Some data (especially data used for visualization validation) were provided in previously prepared documents as embedded text, tables and figures. All original data were checked for inconsistencies and errors (for example, typographical or locational) before incorporation into the visualizations. No data values were changed, but associated fields were formatted in a manner consistent with requirements for input into the C Tech MVS visualization and analysis software.

Site 3DVA data were made up of eight primary categories:

- Historical data – contaminant sources, water management activities and operational policies.
- Map data – legacy aerial photography, map overlays (aerial photography and street maps), and digital elevation models.
- Location data – geographic projections, map coordinates of features (for example, boreholes, groundwater level observation wells, and groundwater monitoring wells) and elevations of features.
- Geologic data – lithostratigraphic horizons (for example, land surface, bedrock surface) and borehole logs (stratigraphic and or lithologic) in Unified Soil Classification System (USCS) nomenclature.
- Hydrogeologic data – synoptic (comprehensive site-wide) groundwater level data from observation, monitoring and extraction wells, potentiometric surfaces and groundwater flow paths.
- Plume contaminant data – groundwater chemistry data including values, qualifiers, detection limits and laboratory methods.
- Temporal data – groundwater level and groundwater chemistry data that were collected at various points in time.
- Treatment system data – location of, and groundwater chemistry data from, treatment system extraction wells, including monthly production (volume of water extracted) in acre-feet and the total mass (in pounds) of PCE and TCE removed for each month of treatment.

All of the above data types were cataloged, evaluated for quality and incorporated in the site 3DVA. The visualizations present these data integrated with and enhanced by historical, map and location data, as discussed below.

5.1 HISTORICAL DATA

The Newmark Source OU boundary used for this evaluation is based on the "*First Five Year Review Report for Newmark Groundwater Contamination Superfund Site, San Bernardino, California*" (EPA 2008) (Figure 1.2). Potential primary source locations and historical land use were identified from legacy aerial photography, particularly of the former Camp Ono facility (Figure 5.1), and reference documents compiled in Table 5.1. Locations of potential contaminant source sites throughout the Source OU were compiled from multiple sources of information (Figure 1.5). Table 5.1 is also a data use matrix that indicates what specific data types in each document were used to support the 3DVA effort.

5.2 MAP DATA

The street map overlay used in the 3DVA was developed by ESRI using ESRI base map data. The street map is included as a service feature under ESRI's ArcGIS product licensing.

5.3 LOCATION DATA

Location data are the 3-D coordinate information (X and Y horizontal and Z vertical), in the specified geographic projection, of the spatial data. All location data for geologic logs, groundwater level observation wells and contaminant monitoring wells were provided by EPA Region 9, the City of San Bernardino and Stantec. Spatial data used to perform the 3DVA include point data (for example, borehole logs and observation wells) and geologic horizons (surfaces). The point data were used to construct the required horizons that, in turn, defined the geometry of the 3-D visualization.

Point spatial data consists of borehole data (for example, lithology logs), monitoring wells for aqueous chemistry sampling and groundwater level observation wells.

The geographic projection for all Newmark Source OU 2-D and 3-D visualizations is North American Datum (NAD) 83, California State Plane, Zone V, Federal Information Processing Standards (FIPS) 405, U.S. Survey feet. All spatial data were either provided in this geographic projection or converted to this geographic projection via ArcGIS or U.S. Army Corps of Engineers (USACE) coordinate conversion software, Corpscon V6. Elevations are referenced in accordance with the North American Vertical Datum of 1988.

5.4 GEOLOGY DATA

One hundred and twenty-nine boring logs were used to construct the lithology and related components (for example, relative hydraulic conductivity [KR]) of the Source OU visualizations. Figure 5.2 shows the spatial distribution of these logs. Their complete listing, with location coordinates, is included as Table 5.2.

Site lithology (unconsolidated soils) was derived from the boring log information available from the EarthVision model previously developed for the NGFM constructed for the site area (Stantec 2008). Stantec furnished an MS Access database with classifications for each of the 129 boring logs.

5.5 HYDROGEOLOGY DATA

The groundwater level observation well network used in the visualization includes 210 wells, many of which also serve as groundwater monitoring wells. Additional wells were also used for groundwater level observations only. Figure 5.3 shows the spatial distribution of groundwater level observation wells. The groundwater level observation wells are tabulated in Table 5.3.

Groundwater level data sources used include:

- 1997 - 2005: MS Excel data file from Stantec

- 2006 - 2007: “Newmark groundwater levels.mdb” from Stantec
- 2006 - 2011: “SBWMD_20120109_GeologyEDD.accdb” from Stantec
- 2010 - 2011: “ITSI_Data_Xfer_11-8-11_Database 9_2011 VOC Data, Well Screens, and Water Levels.xlsx” from ITSI
- 2012: ITSI MS Word document, Stantec (EQuIS) database

The quantity of groundwater level data for the years 2000 and 2007 were insufficient to be included in the water table visualizations.

5.6 PCE DATA

One hundred and seventy-six groundwater monitoring wells have been variously installed and sampled over time within the Source OU. Multiple naming conventions have been applied to these wells, so that some wells have been assigned up to three different identifiers; a “City Well ID,” a “Stantec Well ID,” and an “EPA Well ID.” Furthermore, many of the wells have multiple vertical screen intervals. Figure 5.4 shows the spatial distribution of these wells. A complete listing of groundwater monitoring wells and a cross-listing of their names is included as Table 5.4.

All groundwater chemistry data were received in electronic format. The sources of the groundwater contamination data used for site visualization are listed below (in chronological order from 1987 to 2012):

- 1987-2005 Newmark and Muscoy Plumes and 1987-2008 NW Source Area:
    - “Master well and chemistry database final as of September-2011 modified December 2011 for Phase 3.mdb.” This database was compiled by combining the following datasets:
        - EPA’s Site-wide Database
        - The San Bernardino Database
        - Monitoring and Remediation Optimization System (MAROS) Data

- 2006-2009 Newmark and Muscoy Plumes:
    - EPA Site-wide: “Master well and chemistry database final as of September-2011 modified December 2011 for Phase 3.mdb” (EPA Site-wide, San Bernardino and Monitoring and Remediation Optimization System [MAROS] data)
    - Stantec: “SBDWMD 201111202 ChemEDD2.mdb”

- 2009 NW Source Area:
    - No samples collected because of a contractor transition.

- 2010-2011 NW Source Area data:
    - ITSI: “ITSI_Data_Xfer_11-8-11_Databsase_9_2011 VOC Data, Well Screens, and Water Levels.xlsx”

- 2010-2011 Newmark and Muscoy Plumes:
    - Stantec: “SBDWMD 201111202 ChemEDD2.mdb”

- 2012 NW Source Area:
    - ITSI: “2012 Chemistry.accdb”

- 2012 Newmark and Muscoy Plumes:
    - Stantec: 2012_WG_PCE.xlsx

All of the data were collated into an MS Access database.
Groundwater sampling and analytical data were generated through the following groundwater sampling technologies and methods:

- Passive diffusion bag (PDB)
- Bladder pump (BP)
- Piezometer
- Well head spigot (WHS)

Based on sampling methodology type and depth interval (URS 2004) by well name, the vertical positioning of the PDB samples was assumed to be located at the midpoint of the vertical screened interval with an anticipated 1.0 foot of influence above and below the screen midpoint. Note that monitoring well MW-132A is an exception because the water level was below the middle of the screen. For this reason, it was assumed that the PDB for monitoring well MW-132A was located 1 foot from the bottom of the screen, which is 181 feet below ground surface (bgs). It was assumed that the sample for the BP, piezometer, and WHS-related data was collected from the entire length of the screened interval (URS 2004). Sample type and depth are documented in Table 5.5, the "Master Well List" generated from the "Newmark Master Well and Chemistry Database as of 7-23-2013." All PCE concentration units are measured in micrograms per liter (µg/L).

The analytical detection limits for PCE used within MVS are as follows:

- 1.0 µg/L from 1987 to 2000
- 0.5 µg/L from the May 18, 2000, sampling period to present

5.7 TEMPORAL DATA

Groundwater levels and groundwater contaminant chemistry data are available for the period 1987 to 2012 allowing for the 3DVA to evaluate plume morphology over time. Of the data available, annual (yearly) visualizations of 1997 to 2012 were created, as this time period had the best data coverage. The maximum shallow groundwater level in each observation well for each year that a visualization was created was included to represent the water table. 3DVA Plume morphology relies on the maximum analyte concentration for that year. The assumptions of maximum saturated thickness (the highest water table) and maximum analyte concentration are considered conservative as they produce estimates of plume mass for each yearly visualization.

5.8 TREATMENT SYSTEM DATA

The total treatment system monthly production (volume of water extracted), in acre-feet, and the total pounds of PCE/TCE removed for each month of production from March 2005 through December 2012 for each treatment system were used to evaluate contaminant removal efficiency and estimate the remaining time to achieve restoration. Figure 1.4 shows the extraction wells that make up each treatment system. The treatment system data were provided in a series of *Monthly Summary Treatment Reports for System No. 3610039 – Water Supply Permit No. 03-13-99P-002* and tabulated in an MS Excel spreadsheet "Progress Report Data.xlsx." Table 5.4 lists the treatment systems extraction data used for the treatment systems analyses.

5.9 POTENTIAL CONTAMINANT SOURCE SITES DATA

An online database search was performed to identify sites of potential interest throughout the Source OU with the potential to act as sources of contamination contributing to the Newmark and Muscoy plumes.

On-line searches were ordered through Environmental Data Resources (EDR) and additional data were derived via direct searches of federal and state databases made available to the 3DVA team by EPA Region 9. Data from EDR were received in two deliverables:

- A summary report and associated GIS shapefiles containing the results of a search for environmental sites within the Source OU and surrounding area. A total of 1,921 sites, classified into 52 site type-based databases, were identified by EDR.
- A pdf file containing a listing of production and monitoring wells contained in state and federal databases. (A shapefile of this information was obtained.) A total of 475 wells were identified in the EDR well search; however, it was undetermined which of these were monitoring wells and which were production wells.

The data generated by these searches were subjected to several stages of sorting and reduction efforts designed in consultation with EPA. Data were reviewed to evaluate which sites warranted further inquiry to determine whether they were known sites of concern with active or proposed site investigations or remediation efforts. The results of this sorting effort and secondary inquiry are discussed in Section 9.

6.0 CONSTRUCTION OF VISUALIZATIONS

This section discusses the application software, database summary for visualization, visualization horizons, basic design and orientation of the 3-D visualization, component visualization construction and geostatistical parameters, sensitivity analysis for kriging parameters, PCE plume mass calculations, and QC.

6.1 APPLICABLE SOFTWARE

The project GIS and 2-D visualizations were constructed in ArcGIS Version 10. The 3DVA effort was accomplished using C Tech Development Corporation's MVS software platform. Microsoft Office products and standard text editing software were used to support the geostatistical visualization analyses. In addition to these commercially available software, openly available public-domain software (such as text editors and image viewing) and proprietary software developed by Sundance were used to enhance and expedite the geostatistical visualization.

6.2 DATABASE SUMMARY FOR VISUALIZATION

The compiled PCE database for 1987-2012 (Newmark master well and chemistry database final 7-23-2013.accdb) and the EarthVision database for geologic log classification (EarthVision_Lithology.mdb) were provided to EPA under separate cover. All data used for groundwater level analyses are from the files listed in Section 5.6.

6.3 VISUALIZATION HORIZONS

Three visualization horizons are incorporated into the 3-D visualizations: (1) land surface, (2) top of schist bedrock, and (3) bounding bottom of the visualization. Land surface horizon within the confines of the 3-D visualization was created from the USGS National Elevation Dataset 1/3-arc-second (10 meters) land surface elevations across the Newmark Source OU visualization area. The top of bedrock horizon was extracted from the previously developed EarthVision 3-D lithology model of the area. The bottom boundary of the visualization was set at a uniform -2,000 feet MSL. This elevation ensured that the schist bedrock was present continuously throughout the visualization domain.

6.4 BASIC DESIGN AND ORIENTATION OF THE 3-D VISUALIZATIONS

The 3-D visualizations have a consistent basic design established from the general geologic structure of the area in and around the Newmark Source OU. The general structure of the 3-D visualizations embodies two distinct geologic units: (1) the surficial unconsolidated deposits, and (2) the upper most part of the schist bedrock. These two units are defined by the three visualization horizons described in 6.3.

Figure 6.1 shows the basic structure of the 3-D visualizations; three visualization horizons (land surface, top of bedrock surface, and bottom of visualization) and two geologic units (unconsolidated deposits and bedrock). The focus of subsequent 3-D visualizations is the hydrogeology and occurrence of contaminants in the unconsolidated deposits, represented by the tan colored layer. Bedrock is represented by the gray colored layer.

There is no vertical exaggeration in Figure 6.1, meaning that the visualization is shown at actual scale. Most of the visualizations are shown with a vertical to horizontal exaggeration of 5 to 1 (5:1) to enhance viewing specific features and phenomena. It is important for the reader to be cognizant of the exaggeration when the visualization is viewed. All visualizations indicate whether vertical exaggeration was used, the ratio of any exaggeration, and include a compass symbol for geographic orientation. The land surface shown in Figure 6.1 is represented by the map overlay discussed in Section 5.2 that variably shows street layout and other geographic landmarks within the Source OU and surrounding area with added GIS-based features such as boundary lines, historical land use, and potential contaminant source locations. Other map features are GIS shapefiles that present boundary lines, historical features, and other useful map overlays discussed in Section 5.1.

6.5 COMPONENT VISUALIZATION CONSTRUCTION

6.5.1 GEOLOGY

The geology component visualization is comprised of two elements: (1) the structural geology described in Section 6.4, and (2) the associated lithology (soil type) that was translated into KR using Sundance's proprietary approach to calculating KR. Sundance's approach is based on the established relationship between grain size, phi (a negative logarithmic scale used to classify particle size), and K (Fogg and others 1998). It is important to note that KR is not a direct measure of hydraulic conductivity (K), such as would be derived from performance of well testing. Rather, it is an indexing of K based on lithologic information. As such, it provides a more uniform analysis of site-wide KR to indicate potential migration pathways than can be inferred from manual review of individual K testing results from monitoring wells and soil boring log information.

Site lithology (unconsolidated soil) was characterized from the boring log information available from the EarthVision model (Table 5.2). Figure 6.2 shows the spatial distribution of the EarthVision model lithologic logs and the log description (attribute legend). The log attribute can be interpreted as soil/sediment grain size, with the higher values representing coarser-grained materials and the lower values representing finer-grained sediments. Figure 6.3 shows the distribution of grain sizes present throughout these logs, with three dominant lithologies evident for the site as follows:

- Lithology Type #5 - silt or silty clay
- Lithology Type #11 - poorly to well-graded sand
- Lithology Types #14 and #15 - poorly to well-graded gravel.

The EarthVision log-based lithologies were kriged within Layer 1 (unconsolidated deposits) of the structural geologic visualization (Figure 6.1) using ordinary kriging with adaptive and proportional gridding. The kriged lithology spatial distribution was then reinterpreted as relative (high to low) KR. There are 106,060 discrete lithology/KR nodes within the unconsolidated sediment layer grid (Layer 1) of the structural geologic visualization. Table 6.1 details the major kriging parameters for the geology visualization.

6.5.2 GROUNDWATER/HYDROGEOLOGY

Annual maximum water table elevations (except for 2012, when November 2012 was used) as determined from the shallow groundwater observation well water level data described above were kriged as discrete annual potentiometric surfaces using the same X (horizontal) and Y (vertical) grid resolutions as those used for the geology visualization (shown in Table 6.1). The groundwater level data are not all coincident in time, and some wells were not measured in specific years. Nevertheless, the groundwater level data were spatially and temporally dense enough (except for 2000 and 2007) to provide the basis for reasonable estimates of annual maximum water table elevations throughout the Source OU.

The groundwater level data were incorporated into the MVS visualizations as “Time Control Files (TCF)” that included all annual maximum water levels by year and by observation well. All wells, including those not measured in various years, were included in the TCF files. Years when there were no water levels for wells were signified as “missing” in the data file within the MVS file convention. The advantage of treating the groundwater levels in this manner is the TCF file approach allows for automatic interpolation in time by MVS. As a result, any date-specific water table surface between the bounding first and last years of data in the TCF file can be interpolated. Thus, interpolated water levels were used for wells where no measurement data exist for certain sampling events.

6.5.3 PLUME CONCENTRATION AND MORPHOLOGY

Annual PCE plume visualizations and mass estimates were based on the annual maximum PCE concentrations in observation wells sampled from 1997-2012. Maximum PCE concentrations were kriged (using ordinary kriging) within the unconsolidated deposits (Layer 1) of the structural geology visualization using the gridding and kriging parameters shown in Table 6.2.

6.6 SENSITIVITY ANALYSIS FOR PLUME KRIGING PARAMETERS

An optimum value for the MVS kriging parameter “max-gap” was selected to accommodate the large difference in monitoring well screen intervals (Table 6.2). Max-gap (with units of length) controls the number of discrete concentration values that are placed within the screen intervals of the monitoring wells. The smaller that max-gap is, the greater the number of sample concentrations that are placed at uniformly separated locations within the screen interval. If max-gap becomes too small, there is the possibility that the kriging results (by nature of the geostatistical calculations) will contain concentration estimates that significantly exceed any actual measured value. Therefore, a sensitivity analysis was performed on max-gap to calculate the optimum value as the smallest max-gap value, whereby the resulting PCE plume mass at 5 µg/L becomes stable. This sensitivity analysis was carried out by calculating the PCE plume mass at 5 µg/L for values of max-gap ranging from 5 feet to 100 feet. The mass versus max-gap results were plotted and are shown in Figure 6.4, which indicates that the mass calculation stabilizes with a max-gap greater than 25 feet. A conservative max-gap of 50 feet, based on the results shown in Figure 6.4, was chosen for all site-wide PCE plume kriging to ensure that max-gap did not artificially alter the PCE geostatistical analysis.

6.7 PCE PLUME MASS CALCULATIONS

The mass of PCE comprising any concentration isolevel (for example, 5 µg/L) 3-D plume was calculated for total plumes and subsets of plumes using the volumetrics capabilities provided within MVS. In general, MVS volumetrics computes the volume of each cell in the 3-D visualization grid multiplied by the concentration in each cell, and then sums the results of these calculations and multiplies the sum by the effective porosity to estimate the mass. The normal application of MVS volumetrics assumes a constant effective porosity across the entire visualization domain. The following equation shows this computation:

$$Mass_k\ (lbs) = n_e \times \sum_{i=1}^{n} \left(Concentration_i^k \left(\frac{\mu g}{L}\right) \times Volume_i\ (L)\ \times 2.2 \times 10^{-9} \left(\frac{lbs}{\mu g}\right) \right)$$

Where:

$$k = isolevel\ concentration,\ \frac{\mu g}{L}$$

$$i = grid\ cell$$

$$n = total\ number\ of\ grid\ cells$$

However, applying a constant effective porosity in estimating plume mass over an area as large as the Source OU with varying lithologic properties lowers the accuracy of the resulting mass estimate. Therefore, MVS volumetrics were used to calculate plume mass that allowed for spatially varying effective porosity, thereby improving the accuracy of the associated mass calculations. Instead of multiplying the summation of the concentration times the volume over the entire domain by a constant effective porosity, a spatially varying effective porosity was estimated for each grid cell and multiplied by the concentration and volume of each grid cell according to the following equation:

$$Mass_k\ (lbs) = \sum_{i=1}^{n}\left(\left(Concentration_i\left(\frac{\mu g}{L}\right)\ \times n_{e_i}\right) \times Volume_i\ (L)\ \times 2.2 \times 10^{-9}\ \left(\frac{lbs}{\mu g}\right)\right)$$

Where:

$$n_{e_i} = effective\ porosity\ in\ cell_i\ (dimensionless\ fraction) = f(x, y, z)$$

The effective porosities of various soil and sediment types were taken from McWorter and Sunadana (1977) and are shown in Table 6.3. The highlighted entries in Table 6.3 represent the major unconsolidated sediment types within the Source OU. The lithology distribution in the Source OU provided in the EarthVision model ranged from very fine-grained materials (clays) to very coarse-grained materials (gravels). The effective porosities highlighted in Table 6.3 were distributed across the range of Source OU lithology classifications according to Table 6.4 for the MVS volumetrics calculations of PCE plume mass. A spatially varying effective porosity was computed for all grid cells in the Source OU visualization domain. Within MVS, effective porosity was multiplied times cell concentration to obtain an effective porosity "weighted" concentration for each cell in the domain. These weighted concentrations were then multiplied by the cell volume and summed in MVS volumetrics to estimate the plume mass at any concentration isolevel. Figures 6.5 through 6.7 illustrate this procedure. Figure 6.5 shows a 2005 PCE plume at 3 µg/L. Figure 6.6 shows the estimated effective porosity within the footprint of the 2005 PCE plume (Fig. 6.5). Figure 6.7 shows the effective porosity weighted concentration (the cell-by-cell product of the effective porosity and the concentration).

6.8 QUALITY CONTROL

In addition to QC procedures conducted to assess data quality (Section 4.4), a series of QC steps were employed to assess and manage quality of component visualizations. Component visualizations were used to develop the integrated visualizations discussed in Section 7.

6.8.1 VERIFICATION OF GEOLOGY COMPONENT VISUALIZATION

The geology component visualization was verified by comparison to original geologic log classifications and Stantec's EarthVision geologic results. Figure 6.8 illustrates how the geologic component visualization was verified via comparison of vertical slices through the geologic visualization to the actual lithology input data from the boring logs. The translation of lithology to KR provides a continuum of values and, although the match between slices and logs (not continuous) may not be exact, it is always representative of the input data.

The 3DVA geologic visualization was built from the same database as the Stantec EarthVision visualization. Therefore, corroboration of the two visualizations built with differing software was an important step in verification of the 3DVA geologic results. Figure 6.9 shows a comparison between the EarthVision and 3DVA results for the geology. Each image represents a slice through the two visualizations at 1,732 feet MSL elevation. Shandin and Wiggin Hills are shown in both slices for orientation, and the dashed line on the Shandin Hills slice represents the southeastern extent of the Source

OU visualization. Inspection of the two slices shows a good comparison of lithologies throughout the Source OU boundaries and demonstrates that results are comparable.

6.8.2 VERIFICATION OF HYDROGEOLOGY VISUALIZATION

The hydrogeology visualizations were based on 1997 through 2012 maximum annual water table surfaces (except for the years 2000 and 2007, when quantities of groundwater level data were insufficient). There are no previously contoured annual maximum water table surfaces for direct comparison to the visualized water table surfaces. Nevertheless, the visualized surfaces were verified against representative water table surfaces previously constructed and knowledge of the hydrogeology of the area. Figure 6.10 shows the contoured groundwater level elevations throughout the site in 1983 that were used in the NGFM calibration (Stantec 2008). This figure shows that, in general, shallow groundwater flows down-valley from the northwest to the southeast. Furthermore and significantly, it shows that groundwater flow bifurcates around Shandin Hills. Finally, Figure 6.6 also shows the nominal elevation of groundwater levels throughout the site.

The hydrogeology visualizations of the 3DVA compare well with the overall groundwater level site-wide configuration described above. While the visualized annual water table surface elevations fluctuate over time, as they should in response to changes in groundwater level observations, they all conform to the general pattern of groundwater flow from the northwest to the southeast. For example, the 1997 maximum water table elevation surface visualization (the closest year to the 1983 shallow groundwater elevations shown in Figure 6.10) is shown in Figure 6.11. The 1997 visualized groundwater levels show the consistent pattern of shallow groundwater flow from the northwest to the southeast, with groundwater elevations very similar to those contoured in 1983 (Figure 6.10).

6.8.3 VERIFICATION OF PCE VISUALIZATION

The PCE plume visualizations from 1997 to 2012 were verified by comparison of kriged results to individual sample data from each year. Figure 6.12 illustrates this process for the 1997 plume at 5μg/L. Various contaminant isolevel concentrations were evaluated for each visualization year from 1997 to 2012. No anomalous results, such as the plume indicating a value contradicting an actual sampling concentration, were found.

7.0 RESULTS OF COMPONENT VISUALIZATION AND ANALYSIS

As discussed in Section 6.0, independent visualizations were created for each component 3DVA database (geology, hydrogeology and groundwater chemistry [dissolved phase PCE]) to ensure that no artificial bias was introduced into one component analysis by another component analysis.

Each component visualization is described below and provided in MVS 4-D Interactive Model Player (4DIM) files, a 3-D/4-D viewable format, and as 2-D still images, each produced from the visualization software. A list of final 4DIM files produced for the 3DVA effort is provided in Table 7.1. The files are available electronically as Appendix B.

Viewing the 4DIM visualization files requires C Tech Corporation's Standalone 4D Interactive Model Player freeware that operates under Microsoft Windows and is available at http://client.ctech.com/ (see "Standalone 4DIM Player Installation").

Each 4DIM file contains a series of frames, which are visualizations constructed of various combinations of data that can be viewed and manipulated in 3-D using the computer cursor. Simply click and hold on the visualization, and then move the cursor in any direction until the image can be viewed in the desired 3-D orientation. Alternatively, click on the image without holding and manipulate the image using the four directional arrow keys on the computer keyboard. The reader can also enlarge or shrink the image using the scrolling wheel on the computer mouse. To reposition an enlarged image, hold down the right mouse button and drag the image to the desired location.

The frames can be advanced manually or automatically. Manual advancement is performed using the current frame slide bar or directional arrows at each end of the slide bar, located along the bottom of the file window. Automatic advancements are performed using the RUN tab, located in the lower left corner of the file window. Automated advancement also provides a choice of script designs that appear in a pop-up dialogue box when the RUN tab is selected. The reader is advised that manual advancements are easiest to control and manipulate.

7.1 GEOLOGY VISUALIZATION

The unconsolidated lithologies where the Newmark/Muscoy plumes exist are highly heterogeneous (Figure 7.1). As discussed in prior sections, lithology has been visualized throughout the Source OU in terms of high to low KR in the figures and 4DIM files. Figure 7.2 illustrates the distribution of lowest K_R deposits throughout the Source OU. These lithologies will impede flow and transport of PCE. The low through intermediate K_R deposits are shown in Figure 7.3 and indicate transition zones between low to moderate transport of PCE. Figure 7.4 shows the distribution of the highest K_R deposits, which are comparably more conducive to migration of dissolved phase PCE.

The lithology of the Source OU can also be viewed at any desired angle via slices through the geology visualization. An example of the lithology slices used in the 3DVA of the Source OU is shown in Figure 7.5. The following 4DIM files illustrate the results of 3DVA of site geology:

- *NM1-Newmark geology.4d*
- *NM2-Newmark lithology2.4d*

7.2 GROUNDWATER/HYDROGEOLOGY VISUALIZATION

Groundwater levels throughout the Source OU were visualized as described in Section 6.5.2. A 4DIM file (*NM3-Newmark water levelsrev.4d*) illustrates water level and flow changes in the Source OU from 1997 to 2012. If the 4DIM file is oriented in map view (as shown in Figure 6.1) and 4DIM frames are played continuously, it is evident that the direction of groundwater flow in the aquifer is from the northwest to the south-southeast. If the 4DIM file is oriented to a side view (Figure 7.6) looking from the NW Source Area to the Muscoy plume, and frames are played continuously, it is also evident that water levels have fluctuated significantly over the period of time that site wells have been monitored. These temporal changes are consistent with fluctuating precipitation and recharge of the aquifer that would be expected in the arid climate and groundwater recharge areas in the San Bernardino area (Stantec 2008a). Based on review of hydrographs for the site, groundwater levels for the period 1997 to 2012 have fluctuated up to approximately180 feet in the Source OU (Stantec, 2008a).

7.3 CHEMISTRY VISUALIZATION

7.3.1 TCE CONCENTRATIONS RELATIVE TO PCE AND LACK OF BIODEGRADATION IN PLUME

Although the Muscoy and Newmark plumes have been described as PCE/TCE plumes in the interim ROD documents for the Newmark OU (EPA 1993) and Muscoy OU (EPA 1995), review of the analytical data over time demonstrates that TCE concentrations are quite low compared with the maximum contaminant level (MCL) (5 µg/L). In addition, the number of available data points across the site for detected concentrations of TCE above 5 µg/L was inadequate to support valid geostatistical analysis. As shown in Figure 7.7, there were only four locations throughout the entire Source OU where TCE exceeded 5 µg/L in 2005. Similar patterns of low concentration data and distribution were noted for TCE analytical results from 1997 through 2005.

In addition to temporal evaluation of the Source OU-wide concentrations and distribution of TCE, concentration trend plots were constructed for PCE, TCE and cis-1,2-dichloroethene (cis-1,2-DCE) from monitoring wells in the Northwest Source Area, Muscoy OU and Newmark OU. The trend plots were developed to:

- Establish whether there was any evidence of active biodegradation of PCE > TCE > cis-1,2-DCE, as evidenced by increased concentrations of TCE or cis-1,2-DCE in locations downgradient of locations with detected PCE.
- Document the behavior of TCE relative to PCE to determine if the PCE plume visualizations would duplicate TCE migration and distribution where no evidence of biodegradation was determined to be present.

Figure 7.8 shows three trend plots constructed for PCE, TCE and cis-1,2-DCE based on analytical results for monitoring well CJ-16 from 1995 through 2008. The trend plots demonstrate that there is no evidence of biodegradation of PCE > TCE > cis-1,2-DCE in the CJ-series wells located in the NW Source Area. These same relationships were identified in all downgradient wells examined, demonstrating no biodegradation of PCE throughout the Source OU (Appendix A). The distribution and values for dissolved phase cis-1,2-DCE are shown in Figure 7.9 for 2005. As shown, all samples exhibited concentrations below the MCL of 70 µg/L. These concentrations are further evidence for the lack of biodegradation of PCE across the Source OU.

The trend analyses demonstrate that TCE mimics the behavior of PCE and serves as the basis for applying the results of the PCE plume visualizations to the behavior of TCE in groundwater. Therefore, based on the limited detected presence of TCE in the plumes and the trend analyses, TCE was not further addressed in the 3DVA effort.

7.3.2 PCE Plume Concentration and Distribution

PCE plume visualizations constructed for each year from 1997 to 2012 document changes in plume concentration and morphology from highest concentration (above 30 µg/L) to lowest (5 or 3 µg/L). An example of this type of visualization is provided in a 4DIM file (*NM4-1997 PCE plume.4d*) for the 1997 PCE plume. Still images from the 4DIM file show PCE visualized at 20 µg/L (Figure 7.10) and 10 µg/L (Figure 7.11). In addition to visualizing changing PCE plume concentrations and morphology for each year, visualizations were also developed to document the change in plume distribution and morphology for a given isoconcentration level (for example, 5 µg/L) from 1997 to 2012. These are presented in a 4DIM file (*NM5-PCE at 5 ppb from 1997-2012.4d*) and in Figures 7.12 and 7.13.

These two visualization methods indicate that:

- The highest PCE concentrations for all years were detected in the NW Source Area in groundwater samples collected from monitoring well CJ-10 as shown in a 4DIM file (*NM6-Highest PCE in Plume 1997-2012.4d)* and in Figure 7.14.
- All plume isoconcentration levels have been decreasing with time. Concentrations equal to or above 30 µg/L are limited to groundwater samples collected from monitoring well CJ-10 from 1997 to 2012, as shown in a 4DIM file (*NM6-Highest PCE in Plume 1997-2012.4d*) and in Figure 7.14.
- The distribution of PCE in 2012 at concentrations equal or greater than the MCL (5 µg/L) is limited to the areas near the interim treatment systems and in the NW Source Area in immediate vicinity of monitoring well CJ-10, as shown in a 4DIM file (*NM6-Highest PCE in Plume 1997-2012.4d*) and in Figure 7.14.

8.0 RESULTS OF INTEGRATED VISUALIZATION AND ANALYSIS

Integrated visualizations were created to address specific site questions by combining the component visualizations for potential sources, PCE plume chemistry and lithology as K_R and temporal water table potentiometric surfaces. The independent component visualizations ensure that the correlations of physical features and contaminant properties seen in the integrated visualizations reflect site conditions and are not the result of computational artifacts.

8.1 INTEGRATED VISUALIZATION FOR UNDERSTANDING CONTROLS ON PLUME DISTRIBUTION AND MIGRATION PATHWAY

As shown in Figures 7.11 and 7.12 and associated 4DIM files discussed in Section 7.3, one of the major findings of the PCE plume visualizations is that the PCE plume consistently bifurcates to form both the Newmark and Muscoy plumes in an area located at the northern edge of the Shandin Hills (Figure 8.1). The highest concentration plume within the Source OU is consistently the NW Source Area plume that flows from the northwest to southeast toward Shandin Hills. The Newmark plume (Figure 8.1) was originally designated as a separate OU based on the assumption that the NW Source Area could not be the source for this plume and that a separate source or sources must exist for the Newmark plume on the north side of Shandin Hills. Conversely, it has always been assumed that the NW Source Area Plume was the source for the Muscoy plume.

The integrated visualizations addressed the question of whether the NW Source Area plume could be the source for both the Newmark and Muscoy plumes, as summarized in Figure 8.2, which shows a side view image from the integrated visualization looking to the northeast. The NW Source Area plume is shown at the left, migrating toward Shandin Hills and encountering a confluence of site features that controls whether contaminated groundwater continues to the southeast to form the Muscoy plume or is diverted to the northeast to form the Newmark plume. These features include a subsurface bedrock high, low K_R unconsolidated deposits located at the bedrock high that impede flow, and a fluctuating water table that variably enables contaminated groundwater to pass over the bedrock high, contributing to the Muscoy OU plume.

Three 4DIM files were constructed to illustrate how this confluence of site features controls PCE migration from the NW Source Area to form both the Muscoy or Newmark plumes.

The first 4DIM file (*NM7-Lithology 2001 PCE water table fluctuations.4d*) illustrates the locations of unconsolidated deposits with different K_R properties present within the Source OU. The 2001 PCE plume at 3µg/L is incorporated into the visualization to show the impact of K_R on plume migration and morphology. The first frame of this 4DIM file shows the low K_R unconsolidated deposits encountered at the northwestern edge of Shandin Hills (Figure 8.3). Subsequent frames in the 4DIM file illustrate the migration of the plume from the NW Source Area in response to high and low K_R unconsolidated deposits. The controlling mechanism of plume bifurcation is the temporal change in water table elevation because the K_R of the unconsolidated deposits and bedrock elevation are static and do not change over time.

A second 4DIM file (*NM8-Water level changes point of divergence for nw source plume with clay.4d*) was created to examine the change in and impact of water table elevations from 1997 to 2012 in the area of plume bifurcation. This 4DIM file illustrates that in 2000, when water table elevations are high (Figure 8.4, Frame 31 of the 4DIM file), contaminated groundwater from the NW Source Area Plume can flow over the bedrock high and past the area of low K_R, continuing on to form the Muscoy plume. Conversely, in 2007, when water table elevations are low (Figure 8.5, Frame 93 of the 4DIM file), the integrated visualizations indicate that the NW Source Area plume is then diverted to the northeast to form the Newmark plume on the north side of Shandin Hills.

A third 4DIM file (*NM9-Groundwater pathlines plus 1997 PCE plume and rel K_10-19-2012.4d*) further illustrates the likelihood that the NW Source Area plume is the source for both the Muscoy and Newmark plumes. Groundwater particle tracking path lines from the NGFM (Stantec 2008) were incorporated into the integrated visualizations of lithology as K_R, plume chemistry and water table elevations and the results documented in this 4DIM file. Figure 8.6 presents a still image from this 4DIM file that illustrates the strong correlation between the plume morphologies and the behavior indicated by the integrated 3DVA results and the coincident orientation of groundwater particle tracking pathways from the NGFM (Stantec 2008). Together, these provide multiple lines of evidence for the validity of the sourcing of both the Newmark and Muscoy plumes from the NW Source Area Plume.

8.2 SOURCE OU-WIDE PCE PLUME MASS

The integration of the PCE and K_R component visualizations enabled calculation of masses to be formed of PCE in the plume based on soil effective porosities. The mass of the Source OU-wide PCE plume was calculated for each year (1997 to 2012) and is shown in Figure 8.7. Details of the calculation procedure are presented in Section 6.7.

As shown in Figure 8.7, the Source OU-wide PCE mass has decreased from 1997 through 2012 at all isoconcentration levels (5, 10, and 20 µg/L). The 5 and 10 µg/L curves increase in the 1999 and 2005 to 2006 periods coincident with the commissioning of the Newmark and Waterman Treatment Facilities and the 19th Street Treatment Facility. The increases in these isolevel concentration curves result from adding more sampling locations; and not from an influx of new mass. The sampling network for the site was not consistent until 2005 and 2006 through 2012.

Figure 8.8 presents the Source OU-wide changes in PCE mass for the completed sampling network from 2005 through 2012, indicating that PCE mass has decreased significantly with commissioning the three interim treatment systems. In addition, distribution of mass by concentration for the 2012 site-wide plume ranges from 820 pounds at 5 µg/L to 1 pound at 20 µg/L. Additional information on plume mass for the NW Source Area and the combined Newmark/Muscoy plumes relative to potential ongoing sourcing, as well as treatment efficacy and potential time to achieve restoration for the plume, is presented in Section 9.

9.0 FOUR QUESTIONS POSED FOR PCSM DEVELOPMENT IN SUPPORT OF REMEDIAL DECISION MAKING

Based on the preliminary results of PCSM development, the following questions were subsequently posed by EPA Region 9 related to understanding the groundwater contaminant plume and implications for remedial decision-making:

1. Is there evidence of ongoing sourcing from the NW Source Area?
2. Is it possible for NW Source locations to be sole source of Newmark and Muscoy plumes?
3. Are Newmark/Muscoy plume distribution and mass increasing, decreasing, or not changing with time and installation of treatment systems?
4. Determine if time to achieve restoration using the present treatment systems is reasonable without system modification or additional monitoring points. If not, what can be done to achieve restoration within a reasonable time frame?

Results of the 3DVA effort and related efforts to develop the PCSM provided the basis for answering these questions.

9.1 QUESTION # 1: IS THERE EVIDENCE OF ONGOING SOURCING FROM THE NW SOURCE AREA?

Answer: No

There is no evidence of ongoing sourcing from the NW Source Area. Groundwater from one monitoring well (CJ-10) continues to exhibit relatively consistent PCE concentrations that predominantly range between 30 and 50 µg/L. However, the overall mass of PCE contaminant from the NW Source Area has greatly diminished with time. 3DVA and associated efforts to develop the PCSM indicate that there are no other ongoing sources within the Source OU.

The highest PCE concentrations in groundwater from 1997 to 2012 have consistently been detected in the NW Source Area in samples collected from monitoring well CJ-10, as shown in a 4DIM file (*NM6-Highest PCE in Plume 1997-2012.4d*) and in Figure 7.14. With the exception of the elevated detections at CJ-10, the NW Source Area plume has actually declined in size and mass from 1997 to 2012 (Figures 9.1 through 9.3). Accordingly, as shown in Figure 9.3, there has been a major decrease in the potential for the NW Source Area plume to deliver mass to the Newmark/Muscoy plumes. This lowered potential is evidenced by PCE at a concentration of 5 µg/L with a calculated mass of 450 pounds in 1997 and subsequently decreasing to a calculated mass of 19 pounds as of 2012.

Given the overall decrease in PCE plume size and mass within the NW Source Area plume, questions remain as to why the highest concentrations for PCE continue to be detected at monitoring well CJ-10. Figure 9.4 shows the PCE concentrations for CJ-10 from 1994 to 2012, indicating that the majority of PCE concentrations predominantly range between 30 to 50 µg/L. The CJ-10 well screen is located at a depth near bedrock within low K_R unconsolidated deposits (silt and clay), as shown in a 4DIM file (*NM10-CJ10 ongoing source.4d*) and in Figure 9.5. The CJ-10 well and screen positioning appear to be measuring the capture and slow release of PCE from silts and clays in close proximity to the well screen. Figure 9.6 provides a map view of the location of CJ-10 shown in relation to both the location of Camp Ono facilities and the Cajon Landfill, which are both known to have been potential sources of PCE. The location of well CJ-10 near these facilities and the presence of the low K_R unconsolidated deposits in the subsurface indicate that CJ-10 likely intercepted PCE contamination from one or both of the facilities and that small amounts of PCE mass may have diffused into nearby low K_R units. However, given the overall decrease of PCE concentrations and mass in the NW Source Area plume from 1997 to 2012, it is improbable that the residual mass in the area of CJ-10 will contribute to growth of the Newmark or Muscoy plumes.

9.2 Question # 2: Is it possible for NW Source Area locations to be (or have been) the sole source of Newmark and Muscoy plumes?

Answer: Yes

Based on the 3DVA and other collaborative activities such as the site database search (Section 5.9), there are no indications of any additional significant PCE sources for the Newmark/Muscoy plumes outside of the NW Source Area. The viability of the NW Source Area to have been the source of PCE to both the Newmark and Muscoy plumes is discussed in Section 8.1. The 3DVA effort conclusively defines the Newmark/Muscoy plumes as one plume that bifurcates into two lobes that were each sourced from the vicinity of former Camp Ono facilities and the Cajon Landfill (*NM5-PCE at 5 ppb from 1997-2012.4d*).

Tetra Tech performed an on-line environmental database search for potential locations of interest throughout the entire Source OU to further confirm the NW Source Area as the source for the Newmark and Muscoy plumes. A search of 51 environmental databases identified an initial 1,921 locations, as shown in Figure 9.7. Elimination of duplicate references reduced the total to 1,289 unique locations, of which 27 locations were identified from several State of California databases and 24 were identified from federal databases.

Sites were further sorted based on site type and various indicator attributes to isolate those sites with reasonable potential of having environmental contamination concerns. For example, all dry cleaning sites were retained based on their common association with PCE-contaminated groundwater. Similarly, sites with known spills or actively under state or federal cleanup enforcement were retained. Conversely, sites were eliminated where their listing was based entirely on a low-impact compliance-related issue, such as issuance and monitoring for an air quality permit.

A final list of 46 sites was resolved from the sorting effort, as shown in Figure 9.8. The names of the 46 sites were provided to both the RWQCB and DTSC to identify whether any of the sites was currently under regulatory oversight for site investigation or remediation. Both agencies confirmed that none of the 46 sites was being managed under such regulatory action.

Given the relatively low concentration nature of the plumes, any additional significant source of contamination would appear in the 3-D visualization as an anomalous occurrence of elevated concentrations in an otherwise consistently graded plume. As no such anomalies were found in the plume visualizations throughout the entirety of the Source OU, it was determined that there are no additional significant sources within the Source OU. Consideration was made for potential sites with groundwater contamination at concentrations in the range of that within the plumes that might not appear as an anomaly; however, any potential sites of this nature were determined to be insignificant (assuming concentrations below known plume concentrations) to improbable (assuming concentrations equal to known plume concentrations).

Based on this combined site search and 3DVA-based evaluation, it was determined that the only known and probable source of PCE contamination in the Source OU was the NW Source Area.

9.3 QUESTION # 3: ARE NEWMARK/MUSCOY PLUME DISTRIBUTION AND MASS INCREASING / DECREASING / NOT CHANGING WITH TIME AND INSTALLATION OF TREATMENT SYSTEMS?

Answer: Decreasing

The 3DVA component analysis for PCE from 1997 to 2012 (see Section 7.3.2) demonstrates that the Newmark/Muscoy PCE plumes are decreasing in size, as shown in 4DIM file *NM5-PCE at 5 ppb from 1997-2012.4d* and in Figures 7.12 and 7.13. The decrease in PCE mass for the Newmark/Muscoy plumes is shown in Figure 9.9, which demonstrates that there has been a significant decline in the mass of PCE in the Newmark/Muscoy plumes between 2006 and 2012. The 5 µg/L isoconcentration level plume has decreased from approximately 4,500 pounds to 799 pounds in 6 years. The same decreasing trend is evident for the 10 µg/L isoconcentration level plume with 2012 mass estimates of 14 pounds. Simultaneously, PCE mass values equal to or above 20 µg/L are essentially nonexistent throughout the 2006 to 2012 sampling periods. These trends indicate the Newmark/Muscoy plumes are very low concentration plumes declining significantly in response to treatment.

9.4 QUESTION # 4: DETERMINE IF TIME TO ACHIEVE RESTORATION USING THE PRESENT TREATMENT SYSTEMS IS REASONABLE WITHOUT SYSTEM(S) MODIFICATION OR ADDITIONAL MONITORING POINTS. IF NOT, WHAT CAN BE DONE TO ACHIEVE RESTORATION WITHIN A REASONABLE TIME FRAME?

Answer: Time to achieve restoration is reasonable without system modifications or additional monitoring points.

Historical monthly PCE/TCE removal data from the three interim treatment systems (19^{th} St. Plant Remedy [North], Newmark Plant Remedy and Waterman Plant Remedy) were analyzed to estimate a time to achieve restoration. The total treatment system monthly production, in acre-feet, and the total pounds of PCE/TCE removed for each month of production from March 2005 through December 2012 for each treatment system were used. Table 5.6 details the raw PCE/TCE treatment systems extraction data used for the time to achieve restoration analysis.

The results were used to project future monthly PCE/TCE removal rates. The area under the future projected PCE/TCE removal curves was used to estimate, under strict assumptions, the amount of time required for each treatment system to remove the PCE mass in the Source OU-wide plume remaining as of 2012.

9.4.1 METHODOLOGY

The historical monthly total discharge weighted PCE/TCE removal (pounds per acre-foot) for each system was calculated by dividing the monthly pounds removed by the monthly production for the total treatment system (Table 5.6). The results were plotted as discharge weighted removal versus month for each treatment system.

Figures 9.10 through 9.12 show the resulting graphs for each treatment system as well as the results of the curve fitting exercises performed on the discharge weighted contaminant removal (the blue colored graph in each figure) of each treatment system.

The discharge weighted contaminant removal graphs for the 19^{th} St. North and Newmark treatment systems were smoothed by selecting the majority of peaks in the graph to better define the removal trend over time for each of these treatment systems (the green colored graph in each figure). The 19th St. North and the Newmark treatment systems both show decreasing removal efficiency over time. A power and a linear best-fit trend analysis were performed on each of the "green" trends in the graphs to estimate future (beyond 2012) monthly PCE/TCE removal. The results of the trend analyses are also shown in Figures 9.10 and 9.11 for the 19th St. North and Newmark treatment systems. The correlation coefficients for each trend curve are included in the graphs.

Unlike the 19th St. North and Newmark treatment systems, which both exhibit a continuous reduction in PCE/TCE removal efficiency over time, the historical performance of the Waterman treatment system in terms of removal efficiency increased over time, and then stabilized and finally began to decrease beginning in 2011 (Figure 9.12). A second order polynomial equation was fitted to the historical contaminant removal for the Waterman treatment system to capture this trend, as is shown by the red colored curve on Figure 9.12.

Each of the trend curves was projected forward in time beyond 2012 to estimate how the treatment system may be expected to perform in the future. The key assumptions in these forward projections were:

1. The historical performance of the three treatment systems indicates their future performance. Thus, the trend projections are representative of future removal efficiency. If treatment efficiency decreases significantly, the estimated time to restoration would increase.
2. The PCE mass, as estimated for 2012, represents the total PCE mass in the Source OU. No additional PCE mass will be added to the system in future years. If additional mass is added to the system, the estimated time to restoration would increase.
3. The groundwater flow dynamics are such that the capture zone of each treatment of the three systems is capable of capturing all of the remaining PCE mass within its designated treatment area, based on the present (2012) spatial distribution of PCE. If the treatment systems are ever determined not to be fully capturing the remaining PCE mass, the estimated time to restoration would increase.

The integrated area under each projected (beyond 2012) treatment system efficiency curve represents the amount of mass estimated will be removed in the future by each of the three treatment systems. Using the estimated remaining PCE mass in the system as of 2012 and the integrated area under each projection curve, an approximate amount of additional time required to remove the PCE to concentrations of 5 µg/L and 7 µg/L was estimated. The PCE concentrations are relatively low and near the 5 µg/L MCL throughout each of the three treatment areas; therefore, the 7 µg/L analyses represent a realistic upper bound on the mass remaining in the treatment areas as of 2012.

9.4.2 RESULTS

The estimated times remaining for treatment for the three treatment systems analyzed represent the time to reduce the overall PCE mass to below the equivalent 5 µg/L (MCL) isoconcentration level. The time remaining for treatment was also calculated for achieving a PCE mass equivalent to 7 µg/L (the approximate upper bound of mass).

Figure 9.13 shows the 2012 PCE "plumes" mass at and above 5 µg/L. Figure 9.14 shows the 2012 PCE "plumes" mass at and above 7 µg/L. Figure 9.15 shows the projected time to complete removal of PCE in the 19th St. North treatment area to an equivalent concentration of 5 µg/L or less. This analysis shows that it will take approximately 4 years, regardless of whether the power or linear projections are used, to remove 420 pounds of PCE in the 19th St. North treatment area given the above assumptions. Similarly, Figure 9.16 shows that it will take approximately 2 years, regardless of whether the power or linear projections are used, to remove 131 pounds of PCE at the 7 µg/L equivalent concentration or less, given the above assumptions.

Figure 9.17 shows the projected time to complete removal of PCE in the Newmark treatment area plume to an equivalent concentration of 5 µg/L. This analysis shows that if the continued performance of the Newmark treatment area follows a linear trend, only 56 pounds of the remaining 81 pounds of PCE can be removed by this treatment system before its efficiency reduces to zero. However, the remaining 81 pounds of PCE will be removed in approximately 17 years; given the above assumptions if future contaminant removal efficiency trends according to the power function curve. As an indication of how dilute the PCE plumes were as of 2012, however, Figure 9.18 shows that it will take approximately 2 years regardless of whether the power or linear projections are used to remove 12 pounds of PCE at the 7 µg/L equivalent concentration or less; given the above assumptions.

The analysis of the future performance for the Waterman treatment system is more problematic given its variable historical removal efficiency discussed above. Figure 9.19 shows the projected time to complete removal of 300 pounds of PCE in the Waterman treatment system area to the equivalent concentration of 5 µg/L and below. As shown in Figure 9.19, it will take approximately 9 years to remove the remaining 300 pounds (as of 2012) of PCE to the 5 µg/L threshold. Figure 9.20 shows the estimated time required for the Waterman treatment system to remove PCE mass to an equivalent concentration of 7 µg/L and less. In this case, it will require approximately 2 years to remove the remaining109 pounds of PCE.

10.0 BASELINE RISK ASSESSMENT

Existing site data were reviewed to evaluate potential risks to human health and the environment associated with the Source OU to further evaluate the potential need to perform additional RI efforts at the site.

10.1 HUMAN HEALTH EVALUATION

The Source OU comprises the footprints of both the Newmark and Muscoy OUs, so the preliminary baseline risk assessments issued in 1993 and 1994 for the Newmark and Muscoy OUs were the primary documents used for this evaluation of risks associated with the Source OU. Results from investigations conducted after the preliminary baseline risk assessments were issued and up to the present were also taken into consideration. Additionally, human health and ecological risk was reassessed as part of the 2013 Five-Year Review process. Results of this reassessment are presented in the 2013 Five-Year Review report (EPA 2013). The focus of the preliminary baseline risk assessments was on human health as a result of the nature of the contamination at the site and because of the high urbanization (EPA 1993).

A review of site data indicates that sufficient data exist regarding groundwater and soil gas concentrations for COPCs to evaluate potential risks. However, there are limited to no data regarding soil COPCs and concentrations for soil 0 to 10 feet bgs. Groundwater COPCs identified in the preliminary baseline risk assessments included: PCE, TCE, cis-1,2-DCE, and six other VOCs detected in at least one well (EPA 1993). Conclusions from the Newmark and Muscoy OU preliminary baseline risk assessments assume that groundwater is untreated and distributed to users within San Bernardino. In reality, groundwater distributed to users within San Bernardino is treated to federal and state drinking water standards; thus, risks associated with exposure to any COPCs are mitigated.

In the absence of known sources and given that groundwater is very deep across the majority of the region, vadose zone contamination or remediation was not evaluated in either of the Newmark and Muscoy preliminary baseline risk assessments (EPA 1993; EPA 1994), and both documents state that addressing vadose zone contamination was “not a goal of the interim action.” The approach to vapor intrusion (VI) evaluation has evolved from the time the preliminary baseline risk assessments were conducted. In particular, the EPA released a draft version of VI guidance “*OSWER Draft Guidance on Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils*” (EPA 2002). Per the draft guidance, if volatile chemicals are present in soil or groundwater at a depth of 100 feet or less, VI should be considered as a potential pathway. Since depth to groundwater at the site is greater than 100 feet throughout the majority of the Newmark and Muscoy OUs, the VI pathway likely does not contribute a significant exposure, risk, or hazard (EPA 2013). In addition, analytical results from soil gas samples collected from various potential source areas throughout the Source OU support the conclusion that VI is not a concern at the site (URS 2008). In particular, the groundwater COPCs PCE, TCE, cis-1,2-DCE, as well as Freon 11 and 12, were detected either (1) at concentrations less than their soil gas screening levels (SGSL), or (2) at isolated, deeper locations, indicating that VI is associated with limited risk to human receptors.

As part of the Newmark OU RI, however, some soil sampling was conducted at a suspected source area: the former San Bernardino airport, where groundwater contamination had been identified. The soil sampling was conducted at the suspected location of a solvent disposal pit known as the “Cat Pit” and associated disposal trenches. Soil analytical results indicated that while some VOCs were detected at low concentrations in soil, no TCE or PCE was detected. Therefore, TCE or PCE present no risk to human receptors via VI from soil. Based on the results of the Newmark OU RI, the airport is no longer a suspected source.

10.2 SITE-SPECIFIC EXPOSURE CONSIDERATIONS

The Newmark and Muscoy OU baseline risk assessment reports provide a good basis for understanding risks to human populations if exposed to groundwater under current and potential future land use conditions. Land use within the Source OU is residential, commercial and industrial. As such, potentially exposed populations include residents and workers. Groundwater at the site is currently treated to meet federal drinking water standards before it is distributed (EPA 1993), and contaminant migration is currently under control (EPA 2013). Treatment is anticipated to continue as long as groundwater does not meet these standards. Specific estimates of time until restoration for the three treatment systems are provided in Section 9. Future use of untreated groundwater was evaluated for the baseline risk assessments (EPA 1993; EPA 1994). Risks associated with potable use of in situ groundwater were found to be less than 1E-04, which is within or below the risk management range of 1E-06 and 1E-04 (EPA 2009).

10.3 EXPOSURE ASSESSMENT

Municipal supply wells are present within the site area. As operation of the wells includes long-term monitoring and extracted groundwater is treated to federal drinking water standards (EPA 1993), there is no exposure risk attributable to groundwater. However, should groundwater be distributed without treatment, exposure could occur through residential uses, including through ingestion by drinking or cooking, dermal contact or inhalation of VOCs through bathing and showering, or the use of household appliances such as washing machines. Furthermore, industrial uses of untreated groundwater could expose workers through dermal contact or inhalation (EPA 1993).

In 2014, EPA revised the default values for several exposure parameters for residential exposure to in situ groundwater. Therefore, revised human health risks were calculated for PCE in drinking water. The revised risk calculations and results are presented in Appendix C.

Other potential exposures include VI via soil gas into site structures. Several soil gas investigations have been conducted at the site (Figure 10.1). In particular, the soil gas data gaps investigation conducted at the Newmark site (see Section 10.1 above) supports the conclusion that soil gas contamination presents no significant risks via VI (URS 2008). Additionally, as part of the Newmark OU RI, a screening study of residential indoor air was conducted in 1992 at what was formerly the location of the San Bernardino airport, and more specifically in areas referred to as the “Cat Pit” and disposal trenches. Results of this study did not “indicate a measurable exposure from the soil gas pathway” (EPA 1993). As indicated above, the VI pathway likely does not contribute a significant exposure, risk, or hazard because depth to groundwater at the Site is greater than 100 feet throughout the majority of the Newmark and Muscoy OUs (EPA 2013).

10.4 TOXICITY ASSESSMENT

Noncarcinogenic and carcinogenic risks were assessed in both the preliminary baseline risk assessments conducted for the Newmark and Muscoy OUs. These assessments indicated that risks associated with drinking any untreated groundwater did not exceed 1E-04; that is, no more than one person in a million will contract cancer in their lifetime as a result of environmental exposure. Furthermore, as discussed in the Muscoy OU preliminary baseline risk assessment, once groundwater extracted by municipal wells is treated, “the total estimated lifetime cancer risk for reasonable maximum residential exposure through the domestic use of groundwater would be 1.5E-05” (EPA 1994).

It is important to note that toxicology values and risk assessment methods have been updated since the preliminary baseline risk assessments were conducted. In particular, mutagens — which include the site COC TCE – now involve age-dependent adjustment factors that are used to reflect the greater susceptibility of younger receptors to chemicals that are carcinogenic via a mutagenic mode of action (EPA 2005). As part of the recently conducted 2013 Five-Year Review, changes to toxicity values to site COCs were evaluated. This evaluation used a program that is part of the EPA's Integrated Risk Information System, which updates risk assessment toxicity values as newer scientific information is made available. Changes to toxicity values were identified for site COCs PCE, TCE, cis-1,2-DCE, carbon tetrachloride and methylene chloride (EPA 2013). These updated values result in a change in calculated cancer and noncancer risk values for the site (EPA 2013). In 2014, additional changes to toxicity values for PCE resulted in a change to calculated cancer and noncancer risk values for the site (EPA 2014). The revised risk calculations and results are presented in Appendix C.

Based on a qualitative assessment (no updated risk calculations were prepared) for most COCs, the use of current risk assessment methods and toxicology values would likely result in higher calculated risk values in comparison to risk values calculated for the Newmark and Muscoy OUs preliminary baseline risk assessments. However, these increases are unlikely to be substantial enough to change the net determination of risk. Updated risk calculations were prepared for PCE in drinking water. The revised risk calculations and results are presented in Appendix C and include revisions to toxicity values for PCE as well as to default exposure parameters for residential receptors. The calculations using modified toxicity values for PCE did not change the risk findings for groundwater for the site. In addition, as noted in Section 10.2, a groundwater remedy (treatment) is currently in place so that all groundwater meets federal drinking water standards and groundwater migration has been controlled.

Outstanding toxicological issues have not been identified at the site. However, if risk assessments are to be conducted in the future, the mutagenic mode of action and, if site conditions warrant, the latest VI modeling and guidance should be considered per the *Risk Assessment Guidance for Superfund: Volume 1 Human Health Evaluation Manual (RAGS) Part F* (EPA 2009).

10.5 Risk Characterization

In summary, contaminant levels in groundwater do not pose unacceptable risk to human health as defined by the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as risk levels do not exceed 1E-04. Furthermore, while current concentrations in groundwater do not meet state or federal drinking water standards (an MCL of 5 µg/L) throughout the plumes, groundwater is treated before it is distributed for public consumption and use.

As the Source OU was established to identify source contributions to groundwater, surface soils are less of an issue and there is a sufficient amount of data for groundwater and soil gas to perform quantitative risk calculations if warranted. However, given that a surficial or near-surface contaminant source has not been identified, risk associated with contaminated soils potentially may exist. However, given that release of these chemicals appears to have occurred decades ago, volatile compounds from any surface and near-surface soils associated with a source have likely fully or significantly dissipated.

10.6 Environmental Risks

Because of the highly urbanized land use within the Source OU and given that the exposure pathway is contaminated groundwater, qualitative evaluations of potential current and future environmental risks were conducted during the preliminary baseline risk assessments conducted for the Newmark and Muscoy OUs (EPA 1993; EPA 1994). As discussed in the Interim ROD issued for the Newmark OU in 1993, urbanization “has replaced habitat potential; therefore no significant number of receptors appeared to be present“ and that “there was no indication that future site plans would reinstate habitat and thereby recreate a potential for environmental receptors in the future.” Based on this information and general knowledge of increased development in the area since 1993, it would appear that current environmental conditions do not support suitable habitat for ecological receptors.

Currently, there is no indication at the site that there is a hydrogeologic groundwater to surface water connection. As a result, a complete exposure pathway to potential ecological receptors does not exist (EPA 2013).

For further information regarding the preliminary baseline risk assessments conducted for the Newmark and Muscoy OUs, refer to the Appendix P of the Newmark OU RI/FS (EPA 1993) and Appendix 7 of the Muscoy OU RI/FS (EPA 1994).

11.0 STATUS OF CURRENTLY OPERATING INTERIM REMEDIES

Groundwater P&T systems were selected as interim remedies in the Interim RODs for the Newmark and Muscoy OUs issued in 1993 and 1995. To date, both the Newmark and Muscoy treatment systems have been meeting the following containment RAOs as specified in each of the RODs to:

- Inhibit migration of groundwater contamination into clean portions of the aquifer;
- Limit additional contamination from continuing to flow into the Newmark OU plume area;
- Protect downgradient municipal supply wells south and southwest of the Shandin Hills;
- Begin to remove contaminants from the groundwater plume for eventual restoration of the aquifer to beneficial uses. This project objective is long term rather than an immediate objective of the IRA.

11.1 INTERIM REMEDY SELECTION

The currently operating interim remedies were selected based on the FS conducted for each OU. The interim RODs issued for the Newmark and Muscoy OUs both selected an interim remedy consisting of groundwater extraction (pumping) wells, treatment using liquid phase granular activated carbon (GAC) filtration and post-treatment discharge to the municipal water system as drinking water (EPA 2013). In-depth information regarding the development, screening and detailed evaluation of remedial actions considered for each OU can be found in the RI/FS reports for the Newmark (EPA 1993) and Muscoy OUs (EPA 1994).

An Explanation of Significant Differences (ESD) to the 1993 and 1995 interim RODs was issued by the EPA in 2004 that modified the selected remedies to include an IC program that prohibits groundwater "extraction within the zone of influence of the Newmark and Muscoy systems that would interfere with their integrity" (EPA 2004a). As discussed in Section 1.5, the ICGMP is a site IC, made up of a city ordinance that requires a new permit for any new, non-municipal well or a change in pumping conditions for an existing well. The ICGMP requires consultation with the municipal water district to confirm mutual impacts to the basin's groundwater balance for any new municipal wells. Basin groundwater use is supported by the NGFM, the basin-wide groundwater model maintained by the city and its modeling consultants. The basis of the ICGMP is an agreement among the EPA the City of San Bernardino and water purveyors to keep all production rates constant (EPA 2013).

11.2 COMPONENTS OF THE TREATMENT SYSTEMS

The treatment systems constructed per the 1993 and 1995 RODs for the Newmark and Muscoy OUs are made up of extraction wells, monitoring wells, treatment plants and conveyance systems (EPA 2004). The interim remedy treatment systems are described below.

11.2.1 NEWMARK OU INTERIM REMEDIAL ACTION (IRA) FACILITIES

The Newmark OU treatment system consists of two treatment plants, the Waterman and Newmark plants, a network of EPA-installed extraction wells, and one existing SBMWD production well (Newmark 3) (Figure 11.1). Both plants were constructed from 1997 to 1998 and were declared operational and functional (O&F) in 2000 (EPA 2013).

Currently, the combined discharges from extraction wells EW-2 through EW-5 are is treated at the Waterman plant and the combined discharges from extraction wells EW-6, EW-7 and Newmark 3 are treated at the Newmark plant (Figure 11.1).
The extraction network associated with the Newmark plant is located north of Shandin Hills. Its primary purpose is to prevent further migration of contaminants in groundwater from the north side of Shandin Hills. Extraction well depths associated with the Newmark plant range from 340 to 495 feet bgs with 70 to 190 feet of screened interval (EPA 2013). Groundwater discharged from these extraction wells is treated using seven pairs of 20,000 pounds GAC vessels rated at 75 pounds per square inch (psi) and operated in a lead-lag series configuration. Air stripping plants are also used (EPA 2008). Five monitoring well clusters are associated with the Newmark plant. These wells are used to monitor the effectiveness of the extraction system and to monitor water levels (SBMWD, 2009).

The extraction network associated with the Waterman plant is located along the leading edge of the Newmark plume. Extraction wells associated with this plant have well depths that range from 800 to 1,200 feet bgs and are "screened over a total of 420 to 730 feet" (EPA 2013). The plant is made up of eight 20,000 pounds GAC vessels rated at 75 psi, and air stripping is also used (EPA 2008). Six monitoring well clusters used to monitor water levels and the effectiveness of the remedy are associated with this plant (SBMWD 2009).

A third treatment plant, the 17th Street plant, was installed by SBMWD in the early 1990s within the footprint of the Newmark plume, but is no longer used for remedy operations (EPA 2008).

11.2.2 MUSCOY OU IRA FACILITIES

The Muscoy OU treatment system is made up of the 19th Street North plant and six extraction wells, EW-108, EW-108S, and EW-109 through EW-112 (Figure 11.1). All of the extraction wells began operation in 2005, with the exception of EW-108S, which began operation in 2007 (SBMWD 2009). Discharge from extraction well EW-1 has been redirected from the Waterman plant to the 19th Street North plant, which has greater treatment flow capacity (EPA 2008). The depths of the extraction wells range from 490 to 1,260 feet bgs and are screened over a total of 225 to 1,250 feet (EPA 2013).

The Muscoy extraction network is located upgradient of the toe of the Muscoy plume. The 19th Street North plant treats groundwater discharged from the extraction wells using 12 pairs of 30,000-pound GAC vessels and operated in a lead-lag series configuration. A monitoring well network used to evaluate the effectiveness of the Muscoy plume extraction system consists of eight monitoring well clusters (SBMWD 2009).

11.2.3 SOURCE OU-WIDE FACILITIES

As part of the interim remedies for both the Newmark and Muscoy OUs, Source OU-wide monitoring is conducted to evaluate the effectiveness of the Newmark and Muscoy treatment remedies, evaluate water levels, and assess contamination concentrations site-wide. Monitoring points include production wells, monitoring wells and USGS monitoring well clusters (SBWMD 2009).

According to the draft 2013 Five-Year Review (EPA 2013), in the period between July 2011 and June 2012, monthly treated water volumes ranged from about 1,800 to 2,100 acre-feet and the estimated monthly mass removal from GAC vessels ranged from 13.4 to 19.8 pounds.

As part of O&M activities, the SBMWD submits a semi-annual O&M progress report to the EPA and the California DTSC with information on problems encountered, routine maintenance activities, water level monitoring, whether any deviations from the requirements of the Consent Decree took place, a description of treatment plant operations, and a description of any improvements implemented (EPA 2013).

11.3 Adequacy of the Currently Operating Interim Treatment Facilities

The current treatment systems in place are adequately containing the plumes and are successfully treating groundwater to federal and state drinking water standards. Furthermore, based on conclusions from the 3DVA effort, the treatment systems have been successfully removing contaminant mass and as little as 19 pounds of mass are estimated to remain within the NW Source Area. As discussed in Section 9, the NW Source Area is the area where contaminant sourcing to groundwater has occurred. Subsequent sections provide a summary of the assessment of the nine remedy evaluation criteria (per the National Contingency Plan (40 CFR 300.430(e)(9)) conducted during the 2008 Five-Year Review for the site.

The 2013 Five-Year Review states that:

> "To date, the extraction and treatment systems are functioning as intended by the decision documents. Based on the sampling of monitoring and extraction wells since system start-up, it appears that the Muscoy and Newmark OU containment systems have been successful in meeting the goal of preventing migration of contaminants and reducing contaminant mass. Concentrations downgradient of the extraction wells are generally well below the drinking water standards, where detectible, and the concentrations generally do not exhibit increasing trends where there are verified detections. Opportunities to improve performance and reduce costs have been implemented with proposals for additional optimizations. Institutional controls have now been fully implemented. There have been no changes in the applicable or relevant and appropriate requirements (ARARs) that would affect the protectiveness of the remedy.
>
> "In conclusion, the EPA finds the remedy at the Newmark Superfund Site is protective of human health and the environment." (EPA 2013)

11.4 Overall Protection of Human Health and the Environment, Short-Term Effectiveness and Long-Term Effectiveness

The EPA performed a comparative analysis of the remedial alternatives against the nine evaluation criteria before the interim RODs were issued for both the Newmark and Muscoy OUs and concluded that the selected remedy (extraction, treatment by GAC and transfer to public water supply agency) most fully met the nine criteria (EPA 1993a; EPA 1995). Specific information regarding alternative rankings during the FS can be found in RI/FS reports issued for the Newmark (EPA 1993) and Muscoy OUs (EPA 1994).

According to the 2008 Five-Year Review conducted for the site (EPA 2008), the remedies in place were fully protective of human health and the environment "because exposure pathways that could result in unacceptable risks are being controlled." Furthermore, the treatment systems in place have functioned as intended since the IRAs were completed and sampling and monitoring results indicate that the treatment systems have been successful at preventing the plumes from migrating farther. The review concludes that most monitoring wells within the plumes are exhibiting a decreased trend in contaminant concentrations (EPA 2013).

The 2008 Five-Year Review stated that the long-term protectiveness of the remedies at the site is contingent on the full and permanent implementation of the ICGMP since the remedies were built taking into account all existing water production. The basis of this program is an agreement between the EPA the

City of San Bernardino and water purveyors to keep all production rates constant (EPA 2008). Per the 2013 -Year Review, a permanent ICGMP agreement was reached on June 20, 2010 (EPA 2013).

According to the 2013 Five-Year Review, the remedies in place at the Newmark and Muscoy OUs continue to be protective of human health and the environment and no issues have been identified that would affect current or future protectiveness (EPA 2013).

11.5 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

As part of the 1993 Newmark and 1995 Muscoy OU RODs, chemical-specific and action-specific applicable or relevant and appropriate requirements (ARARs) were identified for the site. A summary of these ARARs, which are the same for each OU, is provided below. A more in-depth discussion is available in Appendix F of the 2013 Five-Year Review (EPA 2013). It should be noted that in the event a standard is different between federal and state regulations, the more stringent of the two is chosen as the ARAR (EPA 2013).

- Safe Drinking Water Act MCLs
    - Federal MCLs – 40 CFR Part 141
    - California MCLs – 22 California Code of Regulations (CCR) §64444
    - California Secondary Drinking Water Standards – 22 CCR §64449

- Air Quality Standards
    - Clean Air Act – 42 U.S.C. §7401
    - California Health and Safety Code §39000
    - South Coast Air Quality Management District (SCAQMD) Regulation XIV, Rule 1401
    - SCAQMD Regulation XIII Rules 1301 through 1313
    - SCAQMD Rules 401, 402 and 403

- Water Quality Standards for Reinjection and Discharges of Treated Water to Surface Water
    - Underground Injection Control Program Regulations – 40 CFR Part 146
    - State Water Resources Control Board Regulation 68-16
    - Santa Ana RWQCB Order No. 91-63-043

- Hazardous Waste Management Regulations
    - California Treatment Plant Requirements
        - Security Requirements – 22 CCR §66264.14
        - Location Standards – 22 CCR §66264.18
        - Precipitation Standards – 22 CCR §66264.25
        - Substantive Closure Requirements – 22 CCR §66264.111-.115
        - Miscellaneous Unit Requirements and Related Substantive Closure Requirements for Air Stripper or GAC Contactor– 22 CCR §66264.600-.603
        - Land Disposal Restrictions – 22 CCR §66268
        - Hazardous Waste Storage Requirements – 22 CCR §66262.34 and 22 CCR §66264.170-.0178

11.6 REDUCTION OF TOXICITY, MOBILITY OR VOLUME

The treatment systems in place are effectively treating groundwater to meet federal drinking water standards and are effectively preventing further migration of the Newmark and Muscoy plumes (EPA

2013). This statement is confirmed by treatment system performance reporting and the results from the 3DVA effort.

3DVA efforts indicate that the treatment systems have successfully been removing VOC mass from the aquifer with approximately 820 pounds of total mass remaining at a concentration of 5.0 µg/L or greater. Treatment system performance reporting indicates that, as of December 2013, 2,922.2 pounds of estimated cumulative mass has been removed (SBMWD 2013).

11.7 IMPLEMENTABILITY

According to the 2008 Five-Year Review, the technologies currently being used as part of both interim remedies are …proven and have been applied extensively" for groundwater monitoring, extraction and conveyance. Further, according to the 2013 Five-Year Review, the "extraction and treatment systems are functioning as intended by the decision documents." As the systems are currently operating and meeting RAOs, the issue of implementability would no longer seem to be a matter for concern.

11.8 COST

According to the 2008 Five Year Report (EPA 2008), the City of San Bernardino obtained a $100 million insurance policy using $50 million from the Consent Decree. Costs from running and maintaining the interim remedies are submitted to the insurance company monthly. The EPA pays electricity costs only for the added differential pressure across the carbon vessels (EPA 2008).

Combined annual operating costs for the Newmark and Muscoy OUs were provided in the 2013 Five-Year Review (EPA 2013). These costs include labor, utilities, materials, sampling and analysis, maintenance, and administrative fees for approved activities as specified in the Consent Decree (EPA 2013). Costs presented in the 2013 Five-Year Review are provided in Table 11-1.

11.9 STATE ACCEPTANCE AND PUBLIC ACCEPTANCE

During the public comment periods before the interim RODs were issued for the Newmark and Muscoy OUs, the public "generally expressed support for Alternative 2, the selected remedy that was comprised of extraction, treatment by GAC and transfer to public water supply agency" (EPA 1995). Water agencies in the region also expressed support for this remedy and the California DTSC concurred (EPA 1993a; EPA 1995).

11.10 PLANNED EXPANSIONS (TWO ADDITIONAL WELLS)

The 19th Street North treatment plant has experienced a decline in production rates of the shallow aquifer production in several of its aquifer extraction wells, including EPA 109 through EPA 112. Between April 2006 and March 2012, shallow aquifer production in these wells had decreased by approximately 68 percent.

As an initial response for this loss of shallow aquifer production, SBMWD installed well packers in EPA 110 and EPA 111 between intermediate and deep aquifer at depths of approximately 700 feet bgs to isolate groundwater extraction to the shallow and intermediate portions of the aquifer system in this area.

New pumps were installed to accommodate the lower extraction rates associated with limiting production to the extraction well upper screen intervals. Although shallow and intermediate aquifer production has been improved with these modifications, water level analysis presented in the monthly progress reports indicate that the current Muscoy OU extraction well network configuration is likely not capable of

sustaining adequate capture in a manner consistent with the performance criteria established in the statement of work.
To improve groundwater capture in this area, SBMWD will install two new shallow aquifer extraction wells, EPA 109S and EPA 112S, adjacent to existing extraction wells EPA 109 and EPA 112.

11.11 REUSE OF TREATED WATER AS DRINKING WATER

Groundwater within the Bunker Hill Basin is the primary source of drinking water for the City of San Bernardino and the City of Riverside, which is located downgradient from the site. Surrounding unincorporated communities also rely on groundwater for their water supply needs (EPA 2008).

By agreement with the SBMWD, extracted water is treated to federal drinking water standards by the currently operating treatment systems and then delivered to the water distribution systems under a California Department of Public Health permit. This permit identifies treatment goals as well as maintenance, sampling and reporting requirements (EPA 2008). The SBMWD maintains the extraction system, evaluates the hydraulic performance, and monitors chemical concentrations in monitoring wells downgradient of the extraction system pursuant to the 2005 Consent Decree (EPA 2013).

12.0 STRATEGY FOR A FINAL ROD

As discussed in Section 9, the interim remedies in place for the Newmark and Muscoy OUs are projected to successfully restore the aquifer to acceptable levels (MCLs) within a reasonable timeframe. This timeframe assumes that the treatment systems will not be modified. Additionally, sampling and 3DVA results have shown that the interim remedies have successfully contained the Newmark and Muscoy plumes. Accordingly, the following sections present elements of a proposed strategy for developing a Final ROD by transitioning the current containment interim remedies in place as the final restoration remedy for the site.

12.1 BASIS FOR TRANSITIONING THE INTERIM REMEDIES AS THE FINAL REMEDY FOR SOURCE OU

Numerous investigations conducted across the site, including from within the NW Source Area, have generated a significant amount of site data but have not resulted in the identification of a discrete source of the contaminant plumes. Based on the 3DVA results, groundwater contaminants are sourced from the NW Source Area, with as little as 19 pounds of PCE contaminant mass remaining in this location. Furthermore, sampling and 3DVA results indicate that the source has dissipated, resulting in two large dilute plumes with approximately 800 pounds of total mass remaining at a concentration of 5.0 µg/L or greater.

Sampling and 3DVA results also indicate that the current groundwater treatment systems have been successfully preventing the plumes from migrating farther down the Bunker Hill Basin while at the same time restoring the aquifer. Coupled with the projected time frames of 4, 9, and 17 years for the three treatment systems to meet RAOs and the significant quantity of existing data generated from prior investigations conducted at the site, additional RI field data collection activities do not appear warranted.

Additionally, human health risks associated with the contaminated groundwater at the site are controlled as groundwater is treated to federal drinking water standards before distribution for public consumption and use. Furthermore, VI likely does not contribute a significant exposure, risk or hazard because the depth of groundwater is greater than 100 feet throughout the majority of the site. Environmental risks to ecological receptors were determined to be minimal during the preliminary baseline risk assessments conducted in 1993 and 1994 for the Newmark and Muscoy OUs based on the highly urbanized setting within the Newmark site (EPA 1993; EPA 1994).

12.2 PROPOSED REMEDY ALTERNATIVES

Based on discussions with the site RPM, the following three remedy alternatives currently exist for the site:

- Cease pump and treat operations
- Continue to operate treatment remedies in place
- Continue to operate treatment remedies in place, modified to optimize effectiveness

Ceasing pump and treat operations at this time is not a feasible alternative because of the mass remaining in the aquifer system, primarily in the downgradient areas of the plume lobes.

As part of the Final ROD, it is proposed that the current interim treatment systems remain in operation as final remedies, with RAOs and ARARs modified to reflect a change in focus from containment to restoration.

Modifications to the treatment systems may potentially take place and may involve optimization of new well placements or the potential to optimize well screen pumping zones. Furthermore, 3DVA results can be used to further support the NGFM modeling efforts.

A Preliminary Close-Out Report (PCOR) can be prepared in accordance with Office of Solid Waste and Emergency Response Directive 9320.2-09A-P, with the Source OU designated as the final OU for the site to document that construction activity at the site has been substantially completed.

12.3 UPDATING RAOS TO INCLUDE A RESTORATION COMPONENT

Currently, RAOs established for the site focus on containment. To transition the current interim remedies to a final remedy, these RAOs will have to be modified to reflect the change in focus from containment to restoration. Current interim RAOs for the site, as well as proposed example language for modified RAOs, are provided below:

Current RAOs:

- To inhibit migration of groundwater contamination into clean portions of the aquifer;
- To limit additional contamination from continuing to flow into the Newmark OU plume area;
- To begin to remove contaminants from the groundwater plume for eventual restoration of the aquifer to beneficial uses. This is a long-term project objective rather than an immediate objective of the IRA.

Proposed RAOs:

- Prevent ingestion of groundwater with contaminant levels exceeding drinking water standards;
- Reduce the toxicity, mobility or volume of contaminants;
- Restore groundwater aquifer COC concentrations to MCLs within a reasonable timeframe to allow for unrestricted beneficial use.

12.4 UPDATING ARARS AND CLEANUP LEVELS TO INCLUDE A RESTORATION COMPONENT

Current ARARs were established for the Newmark and Muscoy OUs and focus on the requirement that treated groundwater meet federal and state drinking water levels prior to distribution to the public. As part of transitioning the current interim remedies in place as final, the ARARs will need to be updated to include a restoration component that provides ARARs for in situ groundwater in addition to retaining the ARARs for treated water.

12.5 STATUTORY DETERMINATIONS

As required per the CERCLA §121 and the National Contingency Plan (NCP), the final remedy must meet statutory requirements and meet the statutory preference for treatment through the implementation of the final remedy. A description of how the interim remedies currently in place at the site meet these requirements is presented in the following sections.

12.5.1 Protection of Human Health and the Environment

As required under CERCLA §121, the selected interim remedial action is protective of human health and the environment (EPA 2013). The interim remedies currently in operation at the site are permanently reducing risks posed to human health and the environment by eliminating, reducing or controlling exposures to human and environmental receptors through treatment and ICs. The extraction systems have been successfully containing the plumes and inhibiting further migration of contaminants downgradient of the site. Based on historical mass removal rates and estimated mass remaining in the system, the timeframe of aquifer restoration and future unrestricted use of groundwater has been projected to be 4, 9 and 17 years for the three treatment systems.

12.5.2 Compliance with ARARs and Other Environmental Criteria

Transitioning the currently operating interim remedies to final remedies will require that the ARARs established for the site be modified to reflect a change in focus from containment to restoration. ARARs identified in the interim RODs issued for the Newmark and Muscoy OUs focus on treating groundwater to federal and state drinking water levels (EPA 1993; EPA 1995). Region 9 will perform a final review of ARARs in association with completion of the Final ROD.

12.5.3 Cost-Effectiveness

Transitioning the currently operating interim remedies to final remedy will provide a number of cost benefits, primarily in the form of future cost avoidance. The following are the major areas of cost avoidance:

- Minimal to no additional RI field work – Costs would be proportionately avoided in contractor procurement, workplan development, field team mobilization, investigations, investigation-derived waste disposal, sample analysis, reporting and general meetings and communications support. The cost avoidance from investigations alone is significant given the expected costs for installing monitoring wells in the difficult drilling environment of the site and to depths exceeding 100 feet. For example, based on similar investigations in the San Bernardino area, the cost for installing a 1,000 foot single-screened monitoring well is approximately $200,000. Therefore, a small investigation effort of installing five to ten new groundwater monitoring wells of similar depth and design would be in the range of $1 million to $2 million. Furthermore, these costs are for labor, materials and construction. They do not include additional costs associated with well development, sampling, sample analysis, data reporting, and long-term maintenance and LTM.

- No FS alternatives analysis – Costs would be avoided because the final remedies already exist in the form of the interim remedies. Costs for identifying any modifications to the remedies would not require alternatives analysis, or at least not at the scale required were no remedies in place.

- Minimal to no design effort – Costs would be avoided in this area if minimal to no additional remedy elements are needed or modifications made. Supplemental remedies and currently anticipated extraction well modifications would be of smaller scale and less complexity than current remedies.

- Minimal to no construction effort – Costs would be avoided in this area if minimal to no additional remedy elements are needed or modifications made. Supplemental remedies or modifications are anticipated would be of smaller scale and less complexity than current remedies.

- Minimal to no increase in LTM effort – Costs would be avoided in this area if minimal to no additional remedy elements are needed or modifications made that require monitoring.

Costs would be incurred should the remedy undergo formal optimization review, to include costs for the review effort (less than $50,000) and costs to implement any recommendations. Based on the 3DVA effort and current site and remedy knowledge, however, it is anticipated that optimization of the groundwater extraction wells and network would result in more efficient targeting of contaminant removal. Therefore, these costs might be directly applied to confirming and designing the recommendations. Costs would be incurred in implementing the recommendations; however, Superfund remedy optimization experience indicates that these recommendations would result in a decrease in overall O&M costs for the remedies. In addition, the recommendations would be expected to result in achieving RAOs in less time, thus lowering the life cycle costs of site restoration.

12.5.4 UTILIZATION OF PERMANENT SOLUTIONS AND ALTERNATIVE TREATMENT TECHNOLOGIES TO THE MAXIMUM EXTENT PRACTICABLE

During the interim remedial actions, both the Newmark and Muscoy plume treatment systems per NCP Section 300.430(a) (1) (ii), were selected with the intent that the systems would be consistent with the final remedy for the site. These remedies include extraction and treatment of VOC-contaminated groundwater via GAC and air stripping along with the ICGMP component. Based on 3DVA results, the current array of extraction wells and treatment facilities is projected to bring groundwater to beneficial use within a timeframe of 4, 9, and 17 years for the three onsite treatment systems.

12.5.5 PREFERENCE FOR TREATMENT AS A PRINCIPAL ELEMENT

The current treatment remedies do not address the statutory preference for remedies that employ treatment to reduce toxicity, mobility and volume as a principal element because they do not involve treatment of principal threats, such as highly toxic or mobile source material. It does, however, meet the NCP expectation to restore contaminated groundwater to beneficial use.

12.5.6 FIVE-YEAR REVIEW REQUIREMENTS

Pursuant to CERCLA Section 121, 42 U.S.C. Section 9621, because hazardous substances remain on-site above health-based levels, the EPA has been conducting a site-wide review once every 5 years after commencement of onsite construction for the Newmark OU interim remedy (EPA 2008), the first of the three treatment systems to be completed and designated O&F. These reviews will continue to be conducted to ensure that the remedy continues to provide adequate protection of human health and the environment.

13.0 FINDINGS AND CONCLUSIONS

The following are the key findings and conclusions resulting from performing the 3DVA effort for the Source OU:

- Existing site data are adequate to verify that Source OU conditions are evidence of site cleanup and, thus, the Source OU does not warrant any additional RI field investigation efforts to support evolving the RAOs from containment to restoration in support of completing a Final ROD.

- Groundwater contamination in the Source OU consists of a large (23 square mile) low concentration (majority of values between 5 and 20 µg/L) PCE plume.

- There are no active sources that would result in an increase in the concentration or size of the present Muscoy/Newmark plumes and specifically no evidence of ongoing sourcing from the NW Source Area. Groundwater from one monitoring well (CJ-10) continues to exhibit relatively consistent PCE concentrations that predominantly range between 30 and 50 µg/L. However, the overall mass of PCE contaminant from the NW Source Area has greatly diminished with time.

- Results of on-line database searches for potential source sites throughout the Source OU indicated that there are no other ongoing sources located within the Source OU.

- The Muscoy/Newmark plumes are one plume system sourced from the NW Source Area, in particular, the former Camp Ono/Cajon Landfill. The plume from the NW Source Area bifurcates at the northern edge of Shandin Hills and forms the Muscoy plume to the southwest under high water level conditions or the Newmark plume to the northeast under low water level conditions. An undulating bedrock surface, extensive units of interfingered high and low K_R alluvial lithologies, and fluctuating water table elevations are responsible for the plume's bifurcation.

- The mass of the PCE plume is decreasing with time, resulting in a significant decrease in the potential for the NW Source Area Plume to deliver mass to the Newmark/Muscoy plumes. Mass reduction is evidenced by PCE at a concentration of 5 µg/L having a mass of 450 pounds in 1997 and subsequently decreasing to a mass of 19 pounds as of 2012. The combined Muscoy/Newmark PCE 5 µg/L isoconcentration level plume mass has decreased from approximately 4,500 pounds to 799 pounds in 6 years (2006 to 2012).

- Contaminant levels in groundwater do not pose unacceptable risk to human health as defined by CERCLA, as risk levels do not exceed 1E-04. Furthermore, while current concentrations in groundwater do not meet state or federal drinking water standards (an MCL of 5 µg/L) throughout the plumes, groundwater is treated before it is distributed for public consumption and use.

- The existing interim remedies appear effective in containment and restoration of the plume and are adequate for reaching site remedial goals within the estimates of time to achieve restoration for each treatment system area. Estimated times to achieve restoration for the contamination captured by three treatment facilities for PCE in groundwater at or above 5 µg/L are: 19th Street North - 4 years; Newmark - 17 years; Waterman - 9 years. Estimations were derived using mass results from the 3DVA for each treatment area (Newmark, 19th Street North, and Waterman) combined with historical monthly PCE removal data from the three interim treatment systems.

- Under criteria for remedy protectiveness established by EPA in line with requirements of the GPRA, the constructed status of the remedies and the existence of ICs support transition of the current remedies from interim to final in support of developing a Final ROD.

The following support the key findings and conclusions:

- Contamination at the site is limited to dissolved phase PCE in groundwater. Based on the results of previous investigations, and the baseline risk assessment, there is no evidence of significant vadose soil or soil vapor contamination.

- Although the Muscoy and Newmark groundwater plumes have been described as PCE/TCE plumes in the interim ROD documents for the Newmark OU(EPA 1993) and Muscoy OU (EPA 1995), review of the analytical data over time demonstrates that TCE concentrations are quite low compared with its MCL (5 µg/L). Additionally, the number of available data points across the site for detected concentrations of TCE at and above 5 µg/L was inadequate for supporting valid geostatistical analysis. However, site-wide trend analyses for TCE demonstrate that TCE mimics the behavior of PCE and serves as a basis for applying the results of the PCE plume visualizations to the behavior of any TCE at the site.

- There is no evidence of biodegradation of PCE > TCE > DCE at the Newmark site. The distribution and values for dissolved phase DCE are below the MCL of 70 µg/L. This fact combined with the values and well trends for TCE, is the principal evidence for this finding.

- The Muscoy OU ROD (EPA 1995) removed Freon-11 and Freon-12 from the list of COCs as a function of risk assessment efforts, which concluded that there was no increased risk to human health and the environment from these compounds at the site.

- The highest PCE concentrations detected for all years monitored (1997 to 2012) were in groundwater samples collected from monitoring well CJ-10 in the NW Source Area. The 3DVA effort was performed using data from the same period (1997 to 2012).

- All plume isoconcentration levels have been decreasing with time. Concentrations equal to or above 30 µg/L are limited to groundwater samples collected from monitoring well CJ-10 from 1997 to 2012.

- The distribution of PCE in 2012 at concentrations equal to or greater than the MCL (5 µg/L) is limited to the areas near the interim treatment systems and in the NW Source Area in immediate vicinity of monitoring well CJ-10.

- The CJ-10 well and screen positioning appear to be measuring the slow release of PCE from the interfingered silts and clays in area of the well. CJ-10 is in the location of Camp Ono facilities and the Cajon Landfill, which are both known to have been potential sources of PCE. The location of well CJ-10 near these facilities and the presence of low K_R unconsolidated deposits in the subsurface indicate that well CJ-10 probably intercepted PCE contamination from one or both of the facilities. However, given the overall decrease of PCE concentrations and mass in the NW Source Area plume from 1997 to 2012, it is improbable that the residual mass in the area of CJ-10 will contribute to growth of the Newmark or Muscoy plumes.

- Integrated visualizations of lithology as K_R, plume chemistry and water table elevations illustrate a strong correlation between the plume morphologies and behavior indicated by the integrated 3DVA results and the coincident orientation of groundwater particle tracking pathways. However, the 3DVA results do not support the need for a layered flow or transport model for the specific purpose of tracking plume behavior and remedial progress.

- Critical assumptions in the time to achieve restoration estimates include:

  - The historical performance of the treatment systems indicates their future performance. The 3DVA team did not identify any evidence to suggest that the performance of the systems will not proceed as they have in the past.
  - The groundwater flow dynamics are such that the capture zone of each treatment system is capable of capturing all the PCE within its designated treatment area, based on the present (2012) spatial distribution of PCE.

- There is no evidence to suggest that the performance of the systems will not proceed as they have in the past. However, present reporting of capture zones for the 19th Street North and Waterman treatment facilities is limited to capture zones designated to a particular flow layer of the NGFM and is not useable for assessing the capture zone of the full vertical aquifer in the treatment areas. There are no capture zone analyses for the Newmark treatment facility.

- Existing geology, hydrogeology and contaminant data sets were judged sufficient to proceed with all geostatistical analyses and visualizations for the site. No additional site data are required at this time for decision making with the 3DVA results.

14.0 RECOMMENDATIONS

The results of 3DVA were used as the basis for recommendations to improve future remedy effectiveness (protectiveness), provide technical improvement, and assist with accelerating site completion. Specific recommendations for cost reduction and for environmental footprint reduction (green remediation) were not a primary focus for this effort.

14.1 RECOMMENDATIONS TO IMPROVE REMEDY EFFECTIVENESS

To improve future remedy effectiveness, the 3DVA team recommends using the results of the 3DVA effort to:

- Achieve consensus on completeness of site characterization, enabling the project to shift from an RI focus to a focus on transitioning the existing remedies from interim to final in support of developing a Final ROD.
- Support improvements in remedy effectiveness through optimization of the groundwater extraction wells and networks for the three treatment systems, resulting in more efficient targeting of contaminant removal.

Future use of 3DVA as the means for evaluating LTM data would support:

- Maintaining a comprehensive, real-time understanding of remedy effectiveness and progress
- Determining and documenting when the site has achieved restoration goals.

14.2 RECOMMENDATIONS TO IMPROVE COST EFFECTIVENESS

It is the opinion of the 3DVA team that transitioning the currently operating interim remedies to final remedies will provide a number of cost benefits, primarily in the form of future cost avoidance through minimal to no additional RI field work, FS alternatives analysis, remedial design, remedial construction and LTM effort. Additional costs savings would be anticipated through optimizing the performance of the extraction well networks and potentially reduced O&M requirements.

14.3 RECOMMENDATIONS FOR TECHNICAL IMPROVEMENT

To help identify opportunities for technical improvement, the 3DVA team recommends using the results of the 3DVA effort to:

- Focus any additional RI field work, notwithstanding that it is the opinion of the 3DVA team that there are no data gaps in site understanding to warrant significant additional field studies.
- Support optimization of the groundwater extraction well network, specifically in light of what is now known about plume extent, morphology, migration pathways and behavior.
- Calibrate the treatment system capture zone analysis to the full plume distribution (horizontal and vertical) across the aquifer versus the six flow model layers currently used for evaluation in the NGFM.
- Evaluate future Source OU LTM data to document that:
    - Continued behavior of PCE at well CJ-10 indicates no increases in concentration.
    - Mass changes predicted for treatment areas are being met. If not, modify time to achieve restoration calculations.

14.4 RECOMMENDATIONS FOR SITE COMPLETION

To help achieve site completion, the 3DVA team recommends using the results of the 3DVA effort to:

- Construct capture zone analyses for treatment areas that encapsulate the entire aquifer for verification of current time to achieve restoration estimates. Currently, capture zones are reported for one or more of six flow model layers in the NGFM for the 19th Street North and Waterman treatment systems only. There is no capture zone analysis available for the Newmark treatment system. Resolving this issue will further support transition of current remedies from interim to final to support development of a Final ROD.

Future use of 3DVA would support:

- Optimizing existing remedy performance to help achieve conditions for restoration.
- Using of LTM data to maintain a comprehensive, real-time understanding of remedy effectiveness and progress.
- Applying visual and geostatistical analyses to demonstrate that the site has achieved restoration goals.

Additional recommendations for helping to achieve site completion include:

- Interim RAOs for the existing treatment systems should be modified to final RAOs to reflect a change from containment to restoration.

14.5 RECOMMENDATIONS FOR ENVIRONMENTAL FOOTPRINT REDUCTION (GREEN REMEDIATION)

No specific recommendations have been provided in this category; however, through applying the above recommendations, the environmental footprint will be reduced. Using 3DVA to understand and monitor clean up progress will accomplish reduced energy consumption, reduced air emissions, conservation of water resources, reduced impact to land and natural resources, and reduced material needs and waste generation by minimizing travel and the need for field investigation and the construction of additional site infrastructure.

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URS. 2008b. *Newmark Groundwater Contamination Superfund Source Operable Unit Remedial Investigation/Feasibility Study Soil Gas Data Gaps Investigation, Report of Findings*.

Weiss Associates. 2001. *Final Subsurface Investigation Report, Soil Gas Survey Lower Apex Parcel and Cat Pit Area San Bernardino Engineering Depot, San Bernardino, California*.

Weiss Associates. 2002. *Final Subsurface Investigation Report, Institution Road Groundwater Wells MW-COE-002 and MW-COE-003 and Soil Borings at Army Wastewater Treatment Plan, San Bernardino Engineering Depot, San Bernardino, California*.

TABLES

Table 1.1
History of Regulatory Actions, Newmark Groundwater Superfund Site

Regulatory Action	Date	Party	Focus and Outcome
Potentially Responsible Parties (PRP) Search	1991	EMSL for Region 9	Identification of PRPs for the site.
CERCLA Screening SI at Camp Ono	1991	Ecology & Environment for Region 9	Investigation focused on Camp Ono and Cajon Landfill area as potential sources. No Further Action was recommended based on inability to associated PCE with Camp Ono.
Newmark OU Interim ROD	1993	Region 9	Interim pump and treat remedy selected for the Newmark OU; remedy inhibits further migration of groundwater contamination.
Muscoy OU Interim ROD	1995	Region 9	Interim pump and treat remedy selected for the Muscoy OU; remedy inhibits further migration of groundwater contamination.
Explanation of Significant Differences (ESD) Supplement to Newmark and Muscoy RODs	2004	Region 9	Non-fundamental change to the remedies associated with the Newmark and Muscoy OUs; implementation of an institutional control program.
Consent Decree	2005	Region 9 and DTSC	Consent Decree amongst EPA, US Army, and the City of San Bernardino for costs incurred. The US Army agreed to pay the City of San Bernardino $69 million. The funds are used to operate the treatment remedies and other cleanup activities.
1st Five Year Review	2008	USACE for Region 9	Assessed whether remedial actions at the site are protective of human health and the environment; results show that the remedy is protective and exposure pathways are controlled.
2nd Five Year Review	2013	USACE for Region 9	Assessed whether remedial actions at the site are protective of human health and the environment; results show that the remedy continues to be protective and exposure pathways are controlled.

DTSC = California Department of Toxic Substances Control
USACE = U.S. Army Corps of Engineers

Table 1.2
Investigations Performed to Date, Newmark Groundwater Superfund Site

Investigation	Date	Investigating Parties	Investigation Focus and Outcome
Initial Source Investigation	1986	URS for Region 9	Inventoried potential sources within the Source OU; 57 potential sites were identified.
Solid Waste Assessment Test conducted at Cajon Sanitary Landfill	1989	IT Corporation	Investigation included the installation of 6 groundwater monitoring wells; 2 upgradient and 4 downgradient of the landfill. Organic pollutants found.
Soil Gas Survey in Muscovy Area (Former Camp Ono Facility)	1989 to 1991	Merklin/CRWQCB	Soil gas sampling was conducted; PCE was detected and trace amounts of TCE was identified.
Newmark OU RI/FS	1990-1993	URS for Region 9	Investigation focused on groundwater Newmark plume groundwater contamination. Source of contamination was identified as being upgradient.
Muscoy OU Interim Sampling Report	1993	URS for Region 9	Results from this sampling event were the main data set used for the RI/FS. Compounds 1,1-dichlorothethane, cis-1,2-DCE, TCE, PCE, and total Freon were the most frequently detected contaminants.
Muscoy OU RI/FS	1994	URS for Region 9	RI/FS was conducted for the Muscoy OU following interim sampling program.
Hydrogeologic Investigation	1995	URS for Region 9	Hydrogeologic investigation to evaluate the leading edge of the Newmark plume and to evaluate the feasibility of remedial pump and treat systems.
Evaluation Monitoring Program Investigation - Cajon Landfill	1995	EMCON for County of San Bernardino Public Works Group	Investigation to assess potential source of groundwater contamination upgradient and downgradient of the landfill. Results indicated that groundwater contamination likely originated from an off-site source, most likely from a former steel mill located on the former Camp Ono property.
Investigation of Potential Non-Military Sources	1996	TechLaw for USACE	Investigation focused on the Northwest Source Area; 107 sites were identified, generally inclusive of the sites identified by URS (1986)
USACE DERP Investigations	1999 to 2003	Kleinfelder, MWH, and Weiss for USACE	Investigations focused on the Camp Ono WWTP, Apex Parcel, Lower Apex Parcel (Ansco), Cat pit, and 17 other Camp Ono potential source areas.
Additional Source Area Identification	1999 to 2006	Region 9	209 sites identified, including majority of those previously identified by URS and Techlaw. Extensive soil gas survey efforts were performed.
RI/FS Soil Gas Investigation	2003 to 2008	URS for Region 9	Soil gas investigation conducted at 6 post-army potential source areas: AM-MEX Specialty Metals, Jack's Disposal, ANCO International, Blackwell

Investigation	Date	Investigating Parties	Investigation Focus and Outcome
			Brothers Automotive, Fred G. Walter & Son, and Grand Central Investment.
Additional Well Installation	2003 to 2008	URS for Region 9	Installation of additional monitoring wells and extraction wells.
Phase II Subsurface Investigation of vacant land near Jack's Disposal	2005	AEI for Paragon Capital Corporation	Phase II investigation conducted at a property in the Source OU. Purpose was to evaluate whether releases of PCE or TCE from a nearby property "Jack's Disposal Services" had impacted soil gas at a vacant property.
Groundwater Contaminant Modeling Study and Web Portal	2007	Geomatrix for Region 9	Purpose was to support groundwater characterization and to develop a web interface to access data.
Long-Term Groundwater Monitoring Optimization, Newmark Superfund Site	2007	GSI for Region 9	Optimization of groundwater monitoring network.
Groundwater Modeling Study	2008	Stantec for SBMWD	Newmark Groundwater Flow Model developed as part of an IC groundwater management program.
San Bernardino Basin Area Refined Basin Flow Model and Solute Transport Model	2009	GeoScience for San Bernardino Valley Municipal Water District	Regional USGS Basin Flow Model used to evaluate basin-wide groundwater management.
Sites of Potential Interest Throughout Source OU	2012	Tetra Tech for Region 9	EDR online environmental database search performed to identify potential sites of interest throughout Source OU. 1,921 initially identified sites reduced to 46, which were submitted to CA RWQCB and DTSC, who subsequently advised 0 sites were of concern.

MWH = Montgomery Watson Harza
RWQCB = California Regional Water Quality Control Board
SBMWD = City of San Bernardino Municipal Water Department
USGS = United States Geological Survey
WWTP = wastewater treatment plant
DERP = Defense Environmental Restoration Program

Table 1.3
Summary of Remedial Efforts, Newmark Groundwater Superfund Site

Remediation	Date	Remediating Parties	Remediation Focus and Outcome
Newmark IRA Construction	1998 - 2000	URS for Region 9	Construction commenced for pump and treat system that would inhibit further VOC contaminant migration in groundwater; system declared operational and functional in 2000.
Newmark OU RA Report	2004	URS for Region 9	Installation of extraction and treatment systems (Newmark Treatment Plant, Waterman Treatment Plant, and 17th Street Treatment Plant) in order to contain contaminants in groundwater.
Muscoy IRA Construction	2005 - 2007	URS for Region 9	Construction commenced for pump and treat system that would inhibit further VOC contaminant migration in groundwater; system declared operational and functional in 2007.
Muscoy OU RA Report	2007	URS for Region 9	Installation of extraction and treatment system (19th Street Treatment Plant) in order to contain contaminants in groundwater.
RA Progress Report	2009	San Bernardino Water District	Progress report regarding O&M of the Newmark and Muscoy OUs, issued per requirements of the Consent Decree.

IRA = Interim Remedial Action

Table 5.1
Document and Data Use Matrix for 3DVA Effort.

Reference		General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
	Type	Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
2005 consent decree (DVD 1)	D	X															
EPA Explanation of Differences (ESD) – Supplement to Newmark and Muscoy RODS with IC program, 2004 (DVD 1)	D	X										X		X		X	
First Five Year Review Report for Newmark Groundwater Contamination Superfund Site, San Bernardino, California, (US EPA, September, 2008). (DVD 1)	D	X															
MAROS databases (DVD 1)	DB						X										
Record of Decision (ROD) for Newmark OU, 1993 (DVD 1)	D	X										X				X	

Reference	Type	General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
		Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
Record of Decision: Newmark Groundwater Contamination, EPA ID:CAD981434517, OU 02, San Bernardino, CA (EPA, March, 24 1995).	D	X															
Remedial Investigation/Feasibility Study (RI/FS) for Muscoy OU, December, 1994	D	X															
Remedial Investigation/Feasibility Study (RI/FS) for Newmark OU, March 1993	D	X															

Reference	Type	General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
		Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
Ecology & Environment, Inc., 1991. CERCLA Screening Site Inspection, Camp Ono, Cajon Boulevard, Interstate 215 and Kendall Drive, San Bernardino, California, San Bernardino County. EPA Hazardous Site Evaluation Division. October 31.	**D**	**X**															
Emcon, 1995. Cajon Landfill Site Assessment Report, Evaluation Monitoring Program. August.	**D**					**X**											
Geoscience, 2009 San Bernardino Basin Area Refined Basin Flow Model and Solute Transport Model Report (DVD 2 and Files on Laptop)	**D** **DB**										**X**						**3DVA - Geology**

Reference	Type	General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
		Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
GSI Environmental, Inc., 2007. Long-Term Groundwater Monitoring Optimization, Newmark, Muscoy, and Source Operable Units, Newmark Superfund Site, San Bernardino, California. August. (DVD 1-covers period of 1999 through 2007)	D	X						X					X		X	X	
Innovative Technology Solutions, Inc. (ITSI), Sept. 2009, Internal Draft, Data Evaluation to Support Remedial Investigation/Feasibility Study (RI/FS) Planning, Source Operable Unit, Newmark Superfund Site, San Bernardino, California (DVD 1 and 2)	D	X	X			X	X										

Reference		General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
	Type	Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
Kleinfelder, Inc. 2000, Report of Findings For Initial Source Investigations, Apex Parcel, Former San Bernardino Engineering Depot (Camp Ono), Source Operable Unit, San Bernardino, California	**D**		**X**			**X**											
Merklin, 1989, Soil Gas Survey, Muscovy Area (Former Camp Ono Facility), San Bernardino, California	**D**		**X**			**X**											
Montgomery Watson, 2000, Initial Soil Vapor Survey in the Vicinity of the San Bernardino Engineering Depot	**D**		**X**			**X**											

Reference	Type	General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
		Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
Science Applications International Corporation (SAIC), 2001, Technical Review of Cajon Landfill Study Documents for the Newmark Superfund Site, Revised Draft Review	**D**		**X**			**X**											
San Bernardino Municipal Water District Interim Report (January 2009) (on DVD 1)	**D**			**X**													**3DVA**
San Bernardino Municipal Water Department Interim Report (First Quarter 2009) DVD 1	**D**			**X**													**3DVA**
Stantec, 2008, Final Baseline Mitigation Plan Newmark and Muscoy Operable Unit Interim Remdial Actions (DVD 1)	**D**	**X**										**X**		**X**		**X**	

Reference	Type	General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
		Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
Stantec, 2008, Draft Newmark Groundwater Flow Model Report (DVD 2 and Files on Laptop)	**D** **DB** **GIS** **MF**										**X**						**3DVA**
URS Corporation (URS), 1986. Investigation of Sources of TCE and PCE Contamination in the Bunker Hill Ground Water Basin, Final Report. Submitted to California Regional Water Quality Control Board, Santa Ana Region, Riverside, California. August.	**D**	**X**	**X**														
URS Group, Inc. 2004, Newmark Groundwater Contamination Superfund Site, Site Wide Field Sampling Plan	**D**					**X**	**X**	**X**									

Reference	Type	General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
		Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
URS, 2004, Figure Summarizing location of all soil gas investigations (DVD 1)	F					X											
URS, March 2008, Newmark Groundwater Contamination Superfund Site Source Operable Unit Interim Remedial Action (DVD 1)	D	X	X									X		X	X	X	
URS, 2008, Newmark Groundwater Contamination Superfund Site Source Operable Unit Remedial Investigation/Feasibility Study Soil Gas Data Gaps Investigation Report of Findings (DVD 1)	D					X											

Reference		General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
	Type	Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
Weiss Associates, 2001. Final Subsurface Investigation Report, Lower Apex Parcel and Cat Pit Area. December.	D		X			X	X										
Weiss Associates, 2002. Institution Road Groundwater Wells MW-COE-002 and MW-COE-003 and Soil Borings at Army Wastewater Treatment Plant. December	D		X			X	X										
Record of Decision (ROD) for Muscoy OU, 1995	D	X										X				X	

Reference	Type	General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
	Type	Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
Summary Table 1 discussed in ITSI draft Source RI/FS report – *referenced in document but not provided in draft or draft final* – may be from URS 2008 document on DVD 1	**S**																
Source Tables 1, 3, 4 from ITSI (?) sent by Kim on 6/24/10	**S**	**X**	**X**														
California Regional Water Quality Control Board (CRWQCB), Santa Ana Region, 1991. Soil Gas Survey, Muscoy Area (Former Camp Ono Facility), San Bernardino, California. May.	**D**		**X**			**X**											

Reference		General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
	Type	Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
Kleinfelder, Inc., 2003. Data Report of Final Investigation, Former San Bernardino Engineering Depot (SBED), Newmark Groundwater Contamination Superfund Site, San Bernardino, California. June.	D		X			X											
Montgomery Watson Harza (MWH), 2002. Final Investigation Report, Initial Soil Vapor Survey in the Vicinity of the San Bernardino Engineering Depot, Camp Ono, San Bernardino, California. September.	D		X			X											
US Army Corps of Engineers (USACE), 2000. Analysis of Soil Gas Screening Levels, Camp Ono Vicinity. February.	D		X			X											

Reference	Type	General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
	Type	Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
Stantec, 2008, Draft Newmark Groundwater Flow Model Report Appendix A, Section A.2 – need lithologic classification of logs in Excel format that was used for data entry into EarthVision for the construction of the geologic model.	**S**									**X**							**3DVA - Geology**
Stantec, 2008, Draft Newmark Groundwater Flow Model Report Appendix A, Section 4.1, Subsections - Historic Groundwater Levels, Lithologic and Well Construction Data, and Physical Features - All compiled data	**DB HC SGIS**								**X**	**X**	**X**						**3DVA - Geology & Water Level Data**

Reference		General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
	Type	Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
Stantec. 2009. Operational Sampling and Analysis Plan. Newmark and Muscoy Operable Units. Interim Remedial Actions. Newmark Groundwater Contamination Superfund Site, San Bernardino, California.	**D**	**X**							**X**								**3DVA - Geology**
Stantec. 1997-2005. Excel file	**S**																**3DVA - Water Level Data, 1997-2005**
Stantec. 2006-2007. Newmark groundwater levels.mdb.	**DB**																**3DVA - Water Level Data, 2006-2007**
Stantec. 2006-2011. SBWMD_20120109_Geology EDD.accdb.	**DB**																**3DVA - Water Level Data, 2006-2011**
EPA. 1997-2005. Site-wide Database, San Bernardino Database, MAROS Data.	**DB**							**X**									**3DVA - PCE data source 1997-2005**

Reference		General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
	Type	Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
EPA Site-wide, 2006-2008. Master well and chemistry database final as of September-2011 modified December 2011 for Phase 3. (compilation of URS, San Bernardino, MAROS)	**DB**							**X**									**3DVA - PCE data source 2006-2008**
Stantec. 2006-2008. SBDWMD 201111202 ChemEDD2.mbd.	**DB**							**X**									**3DVA - PCE data source 2006-2008**
ITSI. ITSI_Data_Xfer_11-8-11_Database 9_2011 VOC Data ,Well Screens, and Water Levels.xlsx. 2010-2011 Data	**S**							**X**			**X**						**3DVA - Water Level Data, PCE data source 2010-2011**
Stantec. SBDWMD 2011112. 2010-2011 Data	**DB**							**X**			**X**						**3DVA - Water Level Data, PCE data source 2010-2011**
Stantec. 2012 Sampling Data (transferred via EQuIS)	**DB**							**X**			**X**						**3DVA - Water Level Data, PCE data source 2012**

Reference	Type	General				Media Chemistry			Geology / Hydrogeology			Risk-Related Info			Remedial Info		Document Use
		Site History & Past Use	Source Area Inv	Post 2007 Site Data	Nearby Site Info	Soil Gas	Surface and Subsurface Soil	Groundwater	Geology - Boring Logs/Well Construction/ Geophysical	Geology- 3D model	Hydrogeology and Groundwater Models	Intended Reuse	Decision Criteria	Pathway Receptor Network	Potential Remedies	Exit Strategies	
Environmental Database Report, 2011. Newmark PCSM Phase II, San Bernardino, CA.	**D**		**X**														**Potential Sources - Tt Site Sorting Study**

X = Data used for 3DVA
D = Document
S = Spreadhseet
DB =Database
HC = Hard Copy/GIS = GIS
Files/MF=Modeling
Files/F=Figure

Table 5.2
Lithology Characterization Borings

Boring Identification	X feet	Y feet	Surface Elevation feet mean sea level
23rdStreetandE.Street	[redacted]	[redacted]	1177.48
31standMt.View	[redacted]	[redacted]	1226.42
40th_Street01N04W14P01S	[redacted]	[redacted]	1365.64
40th_Valencia	[redacted]	[redacted]	1365.64
AntilWellNo.5	[redacted]	[redacted]	1058.57
BaselineandCalifornia	[redacted]	[redacted]	1191.62
Cajon_3/State_Well01N05W03A02S	[redacted]	[redacted]	1890.30
City_601S04W06C04S	[redacted]	[redacted]	1184.72
City_No_101N05W23Q02S	[redacted]	[redacted]	1430.95
CJ-1	[redacted]	[redacted]	1761.76
CJ-10	[redacted]	[redacted]	1717.67
CJ-14	[redacted]	[redacted]	1664.50
CJ-15	[redacted]	[redacted]	1671.21
CJ-2	[redacted]	[redacted]	1690.51
CJ-3	[redacted]	[redacted]	1694.86
CJ-7	[redacted]	[redacted]	1702.40
CJ-8	[redacted]	[redacted]	1770.62
CJ-9	[redacted]	[redacted]	1748.63
Colima	[redacted]	[redacted]	1280.95
Darby01N04W29E01S	[redacted]	[redacted]	1306.91
DevilCanyon_5	[redacted]	[redacted]	1570.81
DTSC1MUNI7C	[redacted]	[redacted]	1312.60
DTSC2MUNI9C	[redacted]	[redacted]	1310.08
DTSC3MUNI11C	[redacted]	[redacted]	1291.93
EllenaBros._2	[redacted]	[redacted]	1481.75
EPAWellNo.108EW-108	[redacted]	[redacted]	1119.51

Boring Identification	X feet	Y feet	Surface Elevation feet mean sea level
EPAWellNo.109EW-109	[redacted]	[redacted]	1135.59
EPAWellNo.110EW-110	[redacted]	[redacted]	1151.52
EPAWellNo.111EW-111	[redacted]	[redacted]	1170.12
EPAWellNo.112EW-112	[redacted]	[redacted]	1182.67
EPAWellNo.1EW-1	[redacted]	[redacted]	1089.90
EPAWellNo.2EW-2	[redacted]	[redacted]	1086.91
EPAWellNo.4EW-4	[redacted]	[redacted]	1073.23
EPAWellNo.5EW-5	[redacted]	[redacted]	1067.15
EPAWellNo.6	[redacted]	[redacted]	1396.62
EPAWellNo.7	[redacted]	[redacted]	1402.97
EW_3	[redacted]	[redacted]	1082.94
FeldheymLibrary1-Casing1	[redacted]	[redacted]	1062.11
FeldheymLibrary1-Casing2	[redacted]	[redacted]	1062.11
FeldheymLibrary1-Casing3	[redacted]	[redacted]	1062.11
FeldheymLibrary2-Casing1	[redacted]	[redacted]	1062.11
FeldheymLibrary2-Casing2	[redacted]	[redacted]	1061.66
FeldheymLibrary2-Casing3	[redacted]	[redacted]	1061.66
Ferg_101N05W25E02S	[redacted]	[redacted]	1372.62
GarnerNo.3	[redacted]	[redacted]	1054.58
GarnerPark_EncantoPark	[redacted]	[redacted]	1122.01
GarnerWellNo.1	[redacted]	[redacted]	1048.31
GarnerWellNo.2	[redacted]	[redacted]	1053.56
GarnerWellNo.4	[redacted]	[redacted]	1056.56
GarnerWellNo.5	[redacted]	[redacted]	1048.18
GarnerWellNo.6	[redacted]	[redacted]	1045.14
GarnerWellNo.7	[redacted]	[redacted]	1053.43
Kendall01N04W21B02S	[redacted]	[redacted]	1357.41
LC_No_101N04W31E01S	[redacted]	[redacted]	1266.59
LC_No_801N04W31F02S	[redacted]	[redacted]	1258.83

Boring Identification	X feet	Y feet	Surface Elevation feet mean sea level
Leroy	[redacted]		1244.19
Lytle_Creek_Reservoir_No_101N04W31N01E			1242.75
Lytle_Creek_Well_Terrace01N05W36R01S			1245.38
Mallory_Well01N04W30M01S			1326.90
MUNI-103			1229.82
Muni-104A			1236.89
MUNI-18			1195.33
MUNI-22			1141.46
MUNI-24			1123.42
Muscoy_101N05W23H01S			1487.03
Muscoy_301N05W23A02S			1510.70
MW-01			1186.22
MW-03			1420.99
MW-08			1477.38
MW-09			1377.57
MW-10			1126.73
MW-127			1539.29
MW-15C			1063.56
MW-16AB			1386.11
MW-37			1085.44
MWCOE001			1622.27
MW-COE-002			1672.53
MW-COE-003			1671.93
MW-COE-005			1766.42
MW-COE-006A			1746.36
MW-COE-007			1759.94
MW-MIA-001			1550.40
MW-MIA-002			1479.78
MW-MIA-003			1434.91

Boring Identification	X feet	Y feet	Surface Elevation feet mean sea level
MW-MIA-004	[redacted]		1423.53
NewmarkMW124APZ124			1578.95
NewmarkMW125APZ125			1561.37
NewmarkMW126AMW126			1552.62
NewmarkMW128			1225.27
NewmarkMW129			1204.67
NewmarkMW130			1178.94
NewmarkMW135			1118.09
NewmarkMW136			1125.59
NewmarkMW137			1150.14
NewmarkMW138			1161.41
NewmarkMW139			1173.46
NewmarkMW6AB			1439.68
NewmarkMW7AB			1436.80
NorthEStreet			1192.54
Paperboard			1326.78
PerrisHill_2			1163.52
PerrisHill_5			1176.67
PerrisHillNo.3			1169.46
PerrisHillNo.4			1171.90
PerrisStreetWell			1112.45
PlantNo.11A			1057.48
PlantNo.12A			1058.47
PlantNo.24A			1249.41
RialtoNo.5			1316.22
SierraHighSchool			1063.56
StilesWell			1063.64
Unknown01N04W20M01S			1360.18
Unknown01N04W22J01S			1274.00

Boring Identification	X feet	Y feet	Surface Elevation feet mean sea level
Unknown01N04W23M01S	[redacted]	[redacted]	1296.34
Unknown01N04W29E03S	[redacted]	[redacted]	1302.93
Unknown01S04W06C03S	[redacted]	[redacted]	1196.04
Upper_201N05W23P02S	[redacted]	[redacted]	1457.18
Well_101N04W23B01S	[redacted]	[redacted]	1362.18
Well_No_101N05W23P04S	[redacted]	[redacted]	1473.08
Well_No_1301S04W06H01S	[redacted]	[redacted]	1163.32
Well_No_1401S04W06J01S	[redacted]	[redacted]	1154.82
Well_No_3001S04W06H02S	[redacted]	[redacted]	1162.56
Well_No_301N05W6A01S	[redacted]	[redacted]	1414.05
Well_No_4A01N05W23H	[redacted]	[redacted]	1402.58
Well_No_501N05W25E01S	[redacted]	[redacted]	1383.50
Well_No_901N04W31P03S	[redacted]	[redacted]	1210.41
WellNo.35	[redacted]	[redacted]	1365.49
WellNo.36	[redacted]	[redacted]	1264.77
WellNo.8A	[redacted]	[redacted]	1263.49

Table 5.3
Groundwater Level Observation Wells

Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
10th_&_J_Street	[redacted]	[redacted]	1113.88
11th/E_St	[redacted]	[redacted]	1094.06
16th_Street_and_Sierra_Way	[redacted]	[redacted]	1135.27
17th_and_Sierra_Way_No._2	[redacted]	[redacted]	1141.95
19th_Street_No._2	[redacted]	[redacted]	1236.25
209701	[redacted]	[redacted]	1476.66
213101	[redacted]	[redacted]	1245.14
23rd_&_E	[redacted]	[redacted]	1175.56
25th_&_North_E_St	[redacted]	[redacted]	1189.00
27th_Street_and_Acacia_Street	[redacted]	[redacted]	1192.00
30th_and_Mt._View	[redacted]	[redacted]	1227.06
31st_and_Mt._View	[redacted]	[redacted]	1253.00
383601	[redacted]	[redacted]	1260.62
40th_Street	[redacted]	[redacted]	1362.00
7th	[redacted]	[redacted]	1057.46
Antil_5	[redacted]	[redacted]	1058.00
Antil_6	[redacted]	[redacted]	1052.51
Baseline_and_California	[redacted]	[redacted]	1185.56
Cajon_2	[redacted]	[redacted]	1887.13
Cajon3	[redacted]	[redacted]	1894.90
CJ010	[redacted]	[redacted]	1711.43
CJ011	[redacted]	[redacted]	1676.07
CJ012	[redacted]	[redacted]	1668.02
CJ014	[redacted]	[redacted]	1664.69
CJ015	[redacted]	[redacted]	1667.88
CJ016	[redacted]	[redacted]	1734.46
CJ017	[redacted]	[redacted]	1738.81
CJ003	[redacted]	[redacted]	1691.89
CJ008	[redacted]	[redacted]	1768.31
DevilCanyon1	[redacted]	[redacted]	1529.80

Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
Devil_Canyon_2	[redacted]		1630.54
Devil_Canyon_4			1907.25
Devil_Canyon_5			1903.69
Devil_Canyon_6			2039.33
Devil_Canyon_7			2041.89
DTSC_001B			1435.39
DTSC_001C			1310.01
DTSC_002B			1307.41
DTSC_002C			1307.29
DTSC_3A			1288.41
DTSC-003B			1287.85
DTSC_3C			1289.07
Electric_Dr._No._01B			1310.86
Electric_Dr._No._01C			1310.01
Electric_Dr._No._02B			1307.41
Electric_Dr._No._02C			1307.29
EPA_Well_No._1			1093.90
EPA_001PA			1093.90
EPA_001PB			1093.90
EPA_002			1091.70
EW-2PA			1091.70
EPA_002PB			1091.70
EPA_003			1090.22
EW-3PA			1090.22
EPA_003PB			1090.22
EPA004			1086.27
EPA_004PA			1086.27
EPA_004PB			1086.27
EPA_Well_No._5			1083.27
EPA_005PA			1083.27
EPA_005PB			1083.27
EPA_006			1396.55

Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
EW-6PA	[redacted]	[redacted]	1395.96
EPA_007	[redacted]	[redacted]	1404.54
EW-7PA	[redacted]	[redacted]	1403.95
EPA_108	[redacted]	[redacted]	1119.26
EW-108A	[redacted]	[redacted]	1119.26
EPA_108PB	[redacted]	[redacted]	1119.26
EPA_108S	[redacted]	[redacted]	1119.46
EPA_109	[redacted]	[redacted]	1137.05
EPA_109PA	[redacted]	[redacted]	1137.05
EPA_109PB	[redacted]	[redacted]	1137.05
EPA_109PC	[redacted]	[redacted]	1137.05
EPA_110	[redacted]	[redacted]	1149.30
EPA_110PA	[redacted]	[redacted]	1145.50
EPA_110PB	[redacted]	[redacted]	1145.48
EPA_110PC	[redacted]	[redacted]	1145.51
EPA_110PD	[redacted]	[redacted]	1145.49
EPA_110PE	[redacted]	[redacted]	1149.30
EPA_111	[redacted]	[redacted]	1169.51
EPA_111PA	[redacted]	[redacted]	1165.68
EPA_111PB	[redacted]	[redacted]	1165.69
EPA_111PC	[redacted]	[redacted]	1165.70
EPA_111PD	[redacted]	[redacted]	1169.49
EPA_112	[redacted]	[redacted]	1181.79
EPA_112PA	[redacted]	[redacted]	1181.79
EPA_112PB	[redacted]	[redacted]	1181.79
GarnerParkA	[redacted]	[redacted]	1120.00
Garner_Park_B	[redacted]	[redacted]	1120.00
Garner_Park_C	[redacted]	[redacted]	1120.00
Gilbert_Street	[redacted]	[redacted]	1123.33
Leroy_Well	[redacted]	[redacted]	1239.67
Lynwood	[redacted]	[redacted]	1236.32
Mallory_No._3	[redacted]	[redacted]	1319.36

Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
Meadowbrook_Park_A	[redacted]		1015.00
Meadowbrook_Park_B			1015.00
Meadowbrook_Park_C			1015.00
Mt_Vernon_Well			1259.00
MW_Colima			1278.00
MWPaperboard			1174.96
MW_State			1564.67
MW002A			1413.75
MW003A			1418.21
MW_004A			1411.28
MW_004B			1411.34
MW005A			1403.58
MW006A			1435.88
MW_006B			1435.88
MW_007A			1436.56
MW007B			1436.55
MW008A			1475.07
MW_008B			1475.07
MW_009A			1378.69
MW_009B			1378.66
MW_010A			1127.77
MW_010B			1127.84
MW_011A			1100.98
MW_011B			1100.96
MW_011C			1100.94
MW_012A			1089.57
MW_012B			1089.49
MW_013A			1079.57
MW_013B			1079.57
MW_013C			1079.54
MW_014A			1076.76
MW_014B			1076.75

Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
MW_015A	[redacted]		1070.21
MW_015B			1070.15
MW_015C			1061.00
MW_016A			1385.19
MW_016B			1385.19
MW_017A			1395.37
MW_017B			1395.37
MW-126			1562.98
MW127A			1545.90
Devil_Canyon_3			1545.90
MW_127B			1545.90
MW-127B			1545.90
MW128A			1215.45
MW_128B			1215.46
MW_128C			1215.48
MW129A			1199.90
MW_129B			1199.45
MW_129C			1199.45
MW-12A			1089.57
MW_130A			1176.09
MW_130B			1175.41
MW_130C			1175.40
MW_MIA_001A			1546.75
MW_MIA_001B			1547.60
MW_MIA_001C			1546.75
MW-132A			1479.30
MW-132B			1478.94
MW-133A			1431.72
MW-133B			1435.39
MW-134			1428.44
MW-135A			1115.11
MW_135B			1115.11

Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
MW_135C	[redacted]	[redacted]	1115.10
MW-136A	[redacted]	[redacted]	1123.08
MW_136B	[redacted]	[redacted]	1123.08
MW_136C	[redacted]	[redacted]	1123.09
MW-137A	[redacted]	[redacted]	1147.28
MW_137B	[redacted]	[redacted]	1147.27
MW_137C	[redacted]	[redacted]	1147.27
MW-138A	[redacted]	[redacted]	1158.77
MW_138B	[redacted]	[redacted]	1158.76
MW_138C	[redacted]	[redacted]	1158.75
MW-139A	[redacted]	[redacted]	1170.93
MW_139B	[redacted]	[redacted]	1170.93
MW_139C	[redacted]	[redacted]	1170.93
MW-13C	[redacted]	[redacted]	1079.54
MW_140A	[redacted]	[redacted]	1304.41
MW_140B	[redacted]	[redacted]	1304.39
MW-140C	[redacted]	[redacted]	1304.39
MW_141A	[redacted]	[redacted]	1122.34
MW-14A	[redacted]	[redacted]	1076.76
MW-15A	[redacted]	[redacted]	1070.21
MW-16A	[redacted]	[redacted]	1385.19
MW-17A	[redacted]	[redacted]	1393.52
MWCOE001A	[redacted]	[redacted]	1619.38
MWCOE001B	[redacted]	[redacted]	1619.25
MWCOE002	[redacted]	[redacted]	1669.47
MWCOE003	[redacted]	[redacted]	1667.23
MWCOE004	[redacted]	[redacted]	1713.00
MWCOE005	[redacted]	[redacted]	1763.83
MWCOE006	[redacted]	[redacted]	1745.00
MWCOE007	[redacted]	[redacted]	1752.40
MWCOE008	[redacted]	[redacted]	1697.30
MWCOE009	[redacted]	[redacted]	1781.00

Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
Newmark_No._1	[redacted]		1244.40
Newmark_No._2			1476.66
Newmark_No._3			1245.14
Newmark_No._4			1248.83
Newmark_MW_10A			1077.00
Newmark_MW_11B			1077.00
Newmark_MW_130A			1077.00
Newmark_MW_4A			1214.58
Newmark_MW_9B			1041.80
Olive_and_Garner_Well			1130.55
Perris_Hill_4			1169.59
Perris_Hill_No._5			1174.96
Perris_Hill_No._3			1164.50
PZ-125			1564.67
Sierra_High_School_A			1077.00
SierraHighSchoolB			1077.00
Sierra_High_School_C			1077.00
State_Street			1214.58
USGS_5th_Sierra			1041.80
Waterman_Avenue			1244.40

Table 5.4.
Groundwater Monitoring Wells with Multiple Names

City Well Identification	Stantec Well Identification	EPA Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
CJ-1	CJ-1	CJ-1	[redacted]		1757.80
CJ-10	CJ-10	CJ-10			1711.43
CJ-11	CJ-11	CJ-11			1676.07
CJ-12	CJ-12	CJ-12			1668.02
CJ-13	CJ-13	CJ-13			1666.77
CJ-14	CJ-14	CJ-14			1664.69
CJ-15	CJ-15	CJ-15			1667.88
CJ-16	CJ-16	CJ-16			1734.46
CJ-17	CJ-17	CJ-17			1738.81
CJ-1A	CJ-1A	CJ-1A			1741.68
CJ-2	CJ-2	CJ-2			1689.45
CJ-3	CJ-3	CJ-3			1691.89
CJ-6	CJ-6	CJ-6			1696.60
CJ-7	CJ-7	CJ-7			1699.24
CJ-8	CJ-8	CJ-8			1768.31
EPA 001	**EPA Well No. 1**	**EW-1**			1093.90
EPA 108	EPA 108	EW-108			1119.26
EPA 108PA	**EW-108A**	**EW-108PA**			1119.26
EPA 108PB	**EW-108B**	**EW-108PB**			1119.26
EPA 109	EPA 109	EW-109			1137.05
EPA 109PA	**EPA 109PA**	**EW-109PZA**			1137.05
EPA 109PB	**EPA 109PB**	**EW-109PZB**			1137.05
EPA 109PC	**EPA 109PC**	**EW-109PZC**			1137.05
EPA 110	EPA 110	EW-110			1149.30

City Well Identification	Stantec Well Identification	EPA Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
EPA 110PA	EPA 110PA	EW-110PZA	[redacted]	[redacted]	1145.50
EPA 110PB	EPA 110PB	EW-110PZB	[redacted]	[redacted]	1145.48
EPA 110PC	EPA 110PC	EW-110PZC	[redacted]	[redacted]	1145.51
EPA 110PD	EPA 110PD	EW-110PZD	[redacted]	[redacted]	1145.49
EPA 110PE	EPA 110PE	EW-110PZE	[redacted]	[redacted]	1149.30
EPA 111	EPA 111	EW-111	[redacted]	[redacted]	1169.51
EPA 111PA	EPA 111PA	EW-111PZA	[redacted]	[redacted]	1165.68
EPA 111PB	EPA 111PB	EW-111PZB	[redacted]	[redacted]	1165.69
EPA 111PC	EPA 111PC	EW-111PZC	[redacted]	[redacted]	1165.70
EPA 111PD	EPA 111PD	EW-111PZD	[redacted]	[redacted]	1169.49
EPA 112	EPA 112	EW-112	[redacted]	[redacted]	1181.79
EPA 112PA	EW-112A	EW-112PA	[redacted]	[redacted]	1181.79
EPA 112PB	EW-112B	EW-112PB	[redacted]	[redacted]	1181.79
EPA 001PA	EW-1PA	EW-1PA	[redacted]	[redacted]	1093.90
EPA 001PB	EW-1PB	EW-1PB	[redacted]	[redacted]	1093.90
EPA 002	EPA Well No. 2	EW-2	[redacted]	[redacted]	1091.70
EPA 002PA	EW-2PA	EW-2PA	[redacted]	[redacted]	1091.70
EPA 002PB	EW-2PB	EW-2PB	[redacted]	[redacted]	1091.70
EPA 003	EPA Well No. 3	EW-3	[redacted]	[redacted]	1090.22
EPA 003PA	EW-3PA	EW-3PA	[redacted]	[redacted]	1090.22
EPA 003PB	EW-3PB	EW-3PB	[redacted]	[redacted]	1090.22
EPA 004	EPA Well No. 4	EW-4	[redacted]	[redacted]	1086.27
EPA 004PA	EW-4PA	EW-4PA	[redacted]	[redacted]	1086.27
EPA 004PB	EW-4PB	EW-4PB	[redacted]	[redacted]	1086.27
EPA 005	EPA Well No. 5	EW-5	[redacted]	[redacted]	1083.27
EPA 005PA	EW-5PA	EW-5PA	[redacted]	[redacted]	1083.27
EPA 005PB	EW-5PB	EW-5PB	[redacted]	[redacted]	1083.27
EPA 006	EPA Well No. 6	EW-6	[redacted]	[redacted]	1396.55
EPA 006PA	EW-6PA	EW-6PA	[redacted]	[redacted]	1396.55
EPA 007	EPA Well No. 7	EW-7	[redacted]	[redacted]	1404.54

City Well Identification	Stantec Well Identification	EPA Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
EPA 007PA	EW-7PA	EW-7PA	[redacted]	[redacted]	1404.54
Devil Canyon 1	Devil Canyon Well No. 1	MUNI-01			1530.00
MUNI-06	MUNI-06	MUNI-06			1406.00
DTSC 001B	Electric Dr. No. 01B	MUNI-07B			1311.07
DTSC 001C	Electric Dr. No. 01C	MUNI-07C			1311.16
DTSC 002B	Electric Dr. No. 02B	MUNI-09B			1307.84
DTSC 002C	Electric Dr. No. 02C	MUNI-09C			1307.51
Olive & Garner	Olive and Garner Well	MUNI-101			1130.00
Baseline & California	Baseline and California	MUNI-102			1185.56
MW State	State Street	MUNI-103			1214.58
19th #1	19th Street No. 1	MUNI-104A			1230.30
19th 2	19th Street No. 2	MUNI-104B			1236.25
Colima	Colima	MUNI-107			1278.00
Mallory 3	Mallory No. 3	MUNI-108			1319.00
MW PAPERBOARD	Paperboard	MUNI-109			1328.00
Cajon 3	Cajon # 3/State Well	MUNI-112			1894.00
Muscoy Mutual 5	Muscoy Mutual 5	MUNI-116			1475.33
DTSC 003A	DTSC 3A	MUNI-11A			1287.34
DTSC 003C	DTSC 3C	MUNI-11C			1287.03
Waterman	Waterman Avenue	MUNI-13			1244.40
31st & Mt. View	31st and Mt. View	MUNI-14			1233.01
Leroy	Leroy Well	MUNI-16			1239.67
27th & Acacia	27th Street and Acacia Street	MUNI-18			1184.07
MUNI-201	MUNI-201	MUNI-201			
17th & Sierra 1	17th Street Sw	MUNI-22			1141.90
16th & Sierra	16th Street and Sierra Way	MUNI-23			1135.27
Gilbert	Gilbert Street	MUNI-24			1123.33
MW 001B	Newmark MW 1B	MW01B			1182.36
MW 001C	Newmark MW 1C	MW01C			1182.36
MW 001D	Newmark MW 1D	MW01D			1182.36

City Well Identification	Stantec Well Identification	EPA Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
MW 001E	**Newmark MW 1E**	**MW01E**	[redacted]	[redacted]	1182.36
MW 001F	**Newmark MW 1F**	**MW01F**	[redacted]	[redacted]	1182.36
MW 002A	**Newmark MW 2A**	**MW02A**	[redacted]	[redacted]	1413.75
MW 002B	**Newmark MW 2B**	**MW02B**	[redacted]	[redacted]	1413.75
MW 003A	**Newmark MW 3A**	**MW03A**	[redacted]	[redacted]	1418.21
MW 003B	**Newmark MW 3B**	**MW03B**	[redacted]	[redacted]	1418.21
MW 004A	**Newmark MW 4A**	**MW04A**	[redacted]	[redacted]	1410.72
MW 004B	**Newmark MW 4B**	**MW04B**	[redacted]	[redacted]	1410.72
MW 005A	**Newmark MW 5A**	**MW05A**	[redacted]	[redacted]	1403.58
MW 005B	**Newmark MW 5B**	**MW05B**	[redacted]	[redacted]	1403.58
MW 006A	**Newmark MW 6A**	**MW06A**	[redacted]	[redacted]	1435.88
MW 006B	**Newmark MW 6B**	**MW06B**	[redacted]	[redacted]	1435.88
MW 007A	**Newmark MW 7A**	**MW07A**	[redacted]	[redacted]	1436.03
MW 007B	**Newmark MW 7B**	**MW07B**	[redacted]	[redacted]	1436.03
MW 008A	**Newmark MW 8A**	**MW08A**	[redacted]	[redacted]	1475.07
MW 008B	**Newmark MW 8B**	**MW08B**	[redacted]	[redacted]	1475.07
MW 009A	**Newmark MW 9A**	**MW09A**	[redacted]	[redacted]	1377.81
MW 009B	**Newmark MW 9B**	**MW09B**	[redacted]	[redacted]	1377.81
MW 010A	**Newmark MW 10A**	**MW10A**	[redacted]	[redacted]	1127.42
MW 010B	**Newmark MW 10B**	**MW10B**	[redacted]	[redacted]	1127.42
MW 010C	**Newmark MW 10C**	**MW10C**	[redacted]	[redacted]	1127.42
MW 011A	**Newmark MW 11A**	**MW11A**	[redacted]	[redacted]	1100.52
MW 011B	**Newmark MW 11B**	**MW11B**	[redacted]	[redacted]	1100.52
MW 011C	**Newmark MW 11C**	**MW11C**	[redacted]	[redacted]	1100.52
MW 126	MW-126	MW-126	[redacted]	[redacted]	1562.98
MW 127A	**Newmark MW 127A**	**MW-127A**	[redacted]	[redacted]	1545.90
MW 127B	**Newmark MW 127B**	**MW-127B**	[redacted]	[redacted]	1545.90
MW 128A	**Newmark MW 128A**	**MW-128A**	[redacted]	[redacted]	1215.04
MW 128B	**Newmark MW 128B**	**MW-128B**	[redacted]	[redacted]	1215.04
MW 128C	**Newmark MW 128C**	**MW-128C**	[redacted]	[redacted]	1215.04

City Well Identification	Stantec Well Identification	EPA Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
MW 129A	**Newmark MW 129A**	**MW-129A**	[redacted]	[redacted]	1199.32
MW 129B	**Newmark MW 129B**	**MW-129B**	[redacted]	[redacted]	1198.91
MW 129C	**Newmark MW 129C**	**MW-129C**	[redacted]	[redacted]	1198.92
MW 012A	**MW-12A**	**MW12A**	[redacted]	[redacted]	1088.51
MW 012B	**MW-12B**	**MW12B**	[redacted]	[redacted]	1088.51
MW 012C	**MW-12C**	**MW12C**	[redacted]	[redacted]	1088.53
MW 130A	**Newmark MW 130A**	**MW-130A**	[redacted]	[redacted]	1175.22
MW 130B	**Newmark MW 130B**	**MW-130B**	[redacted]	[redacted]	1174.58
MW 130C	**Newmark MW 130C**	**MW-130C**	[redacted]	[redacted]	1174.56
MW MIA 001A	**MW-131A**	**MW-131A**	[redacted]	[redacted]	1546.75
MW MIA 001B	**MW-131B**	**MW-131B**	[redacted]	[redacted]	1546.75
MW MIA 001C	**MW-131C**	**MW-131C**	[redacted]	[redacted]	1546.75
MW MIA 002A	**MW-132A**	**MW-132A**	[redacted]	[redacted]	1479.30
MW MIA 002B	**MW-132B**	**MW-132B**	[redacted]	[redacted]	1478.94
MW MIA 003A	**MW-133A**	**MW-133A**	[redacted]	[redacted]	1435.39
MW MIA 003B	**MW-133B**	**MW-133B**	[redacted]	[redacted]	1435.39
MW MIA 004	**MW-134**	**MW-134**	[redacted]	[redacted]	1428.44
MW 135A	MW-135A	MW-135A	[redacted]	[redacted]	1111.28
MW 135B	MW-135B	MW-135B	[redacted]	[redacted]	1111.28
MW 135C	MW-135C	MW-135C	[redacted]	[redacted]	1111.30
MW 136A	MW-136A	MW-136A	[redacted]	[redacted]	1121.67
MW 136B	MW-136B	MW-136B	[redacted]	[redacted]	1121.63
MW 136C	MW-136C	MW-136C	[redacted]	[redacted]	1121.61
MW 137A	MW-137A	MW-137A	[redacted]	[redacted]	1144.05
MW 137B	MW-137B	MW-137B	[redacted]	[redacted]	1144.10
MW 137C	MW-137C	MW-137C	[redacted]	[redacted]	1144.07
MW 138A	MW-138A	MW-138A	[redacted]	[redacted]	1156.87
MW 138B	MW-138B	MW-138B	[redacted]	[redacted]	1156.92
MW 138C	MW-138C	MW-138C	[redacted]	[redacted]	1156.99
MW 139A	MW-139A	MW-139A	[redacted]	[redacted]	1168.76

City Well Identification	Stantec Well Identification	EPA Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
MW 139B	MW-139B	MW-139B	[redacted]		1168.71
MW 139C	MW-139C	MW-139C			1168.85
MW 013A	**MW-13A**	**MW13A**			1078.36
MW 013B	**MW-13B**	**MW13B**			1078.36
MW 013C	**MW-13C**	**MW13C**			1078.29
MW 014A	**MW-14A**	**MW14A**			1075.73
MW 014B	**MW-14B**	**MW14B**			1075.73
MW 014C	**MW-14C**	**MW14C**			1075.73
MW 015A	**MW-15A**	**MW15A**			1069.38
MW 015B	**MW-15B**	**MW15B**			1069.38
MW 015C	**MW-15C**	**MW15C**			1069.38
MW 016A	**MW-16A**	**MW16A**			1384.25
MW 016B	**MW-16B**	**MW16B**			1384.25
MW 017A	**MW-17A**	**MW17A**			1392.63
MW 017B	**MW-17B**	**MW17B**			1392.69
MWCOE001A	MWCOE001A	MWCOE001A			1619.38
MWCOE001B	MWCOE001B	MWCOE001B			1619.25
MWCOE002	MWCOE002	MWCOE002			1669.47
MWCOE003	MWCOE003	MWCOE003			1667.23
MWCOE004	MWCOE004	MWCOE004			1713.00
MWCOE005	MWCOE005	MWCOE005			1763.83
MWCOE006	MWCOE006	MWCOE006			1745.00
MWCOE007	MWCOE007	MWCOE007			1752.40
MWCOE008	MWCOE008	MWCOE008			1697.30
MWCOE009	MWCOE009	MWCOE009			1781.00
PZ-124	PZ-124	PZ-124			1583.55
PZ-125	PZ-125	PZ-125			1564.88
EPA 108S	EW-108S	EW-108S			1119.46
MW 140A	**MW-140A330**	**MW-140A**			1305.25
MW 140B	MW-140B	MW-140B			1305.25

City Well Identification	Stantec Well Identification	EPA Well Identification	X feet	Y feet	Surface Elevation feet mean sea level
MW 140C	MW-140C	MW-140C	[redacted]		1305.25
MW 141A	MW-141A	MW-141A			1122.78

Table 5.5
Master Well List Generated from Newmark Master Well and Chemistry Database.

City Well Identification	Stantec Well Identification	EPA Well Identification	Easting	Northing	Elevation	Depth Sampled From (feet below ground surface [ft bgs])	Depth Sampled From (ft bgs)	Operable Unit Name	Screen Length (ft)	Sample Type	Passive Diffusion Bag (PDB) Sample Location (ft bgs)
CJ-1	CJ-1	CJ-1	[redacted]	[redacted]	1757.80	276.00	316.00	Source	40.00	Redi-Flo 4	
CJ-10	CJ-10	CJ-10	[redacted]	[redacted]	1711.43	136.00	145.00	Source	9.00	Bladder Pump	
CJ-11	CJ-11	CJ-11	[redacted]	[redacted]	1676.07	179.00	189.00	Source	10.00	Bladder Pump	
CJ-12	CJ-12	CJ-12	[redacted]	[redacted]	1668.02	246.00	256.00	Source	10.00	Bailer	
CJ-13	CJ-13	CJ-13	[redacted]	[redacted]	1666.77	245.00	255.00	Source	10.00	Bailer	
CJ-14	CJ-14	CJ-14	[redacted]	[redacted]	1664.69	245.00	255.00	Source	10.00	Bailer	
CJ-15	CJ-15	CJ-15	[redacted]	[redacted]	1667.88	355.00	378.00	Source	23.00	Redi-Flo 4	
CJ-16	CJ-16	CJ-16	[redacted]	[redacted]	1734.46	250.00	270.00	Source	20.00	Redi-Flo 2	
CJ-17	CJ-17	CJ-17	[redacted]	[redacted]	1738.81	139.00	159.00	Source	20.00	Redi-Flo 2	
CJ-1A	CJ-1A	CJ-1A	[redacted]	[redacted]	1741.68	311.00	351.00	Source	40.00	Redi-Flo 4	
CJ-2	CJ-2	CJ-2	[redacted]	[redacted]	1689.45	278.00	320.00	Source	42.00	Redi-Flo 4	
CJ-3	CJ-3	CJ-3	[redacted]	[redacted]	1691.89	290.00	330.00	Source	40.00	Redi-Flo 4	
CJ-6	CJ-6	CJ-6	[redacted]	[redacted]	1696.60	240.00	280.00	Source	40.00	Redi-Flo 2	
CJ-7	CJ-7	CJ-7	[redacted]	[redacted]	1699.24	278.00	318.00	Source	40.00	Redi-Flo 4	
CJ-8	CJ-8	CJ-8	[redacted]	[redacted]	1768.31	234.00	244.00	Source	10.00	Bladder Pump	
EPA 001	EPA Well No. 1	EW-1	[redacted]	[redacted]	1093.90	600.00	1190.00	Newmark	590.00	Well head spigot	
EPA 108	EPA 108	EW-108	[redacted]	[redacted]	1119.26	510.00	590.00	Muscoy	80.00	Well head spigot	
EPA 108	EPA 108	EW-108	[redacted]	[redacted]	1119.26	670.00	1000.00	Muscoy	330.00	Well head spigot	
EPA 108PA	EW-108A	EW-108PA	[redacted]	[redacted]	1119.26	370.00	390.00	Muscoy	20.00	Piezometer	
EPA 108PB	EW-108B	EW-108PB	[redacted]	[redacted]	1119.26	740.00	760.00	Muscoy	20.00	Piezometer	
EPA 108S	EW-108S	EW-108S	[redacted]	[redacted]	1119.46	265.00	285.00	Unknown	20.00	Well head spigot	
EPA 108S	EW-108S	EW-108S	[redacted]	[redacted]	1119.46	305.00	350.00	Unknown	45.00	Well head spigot	
EPA 108S	EW-108S	EW-108S	[redacted]	[redacted]	1119.46	370.00	450.00	Unknown	80.00	Well head spigot	

City Well Identification	Stantec Well Identification	EPA Well Identification	Easting	Northing	Elevation	Depth Sampled From (feet below ground surface [ft bgs])	Depth Sampled From (ft bgs)	Operable Unit Name	Screen Length (ft)	Sample Type	Passive Diffusion Bag (PDB) Sample Location (ft bgs)
EPA 109	EPA 109	EW-109	[redacted]	[redacted]	1137.05	260.00	330.00	Muscoy	70.00	Well head spigot	
EPA 109	EPA 109	EW-109	[redacted]	[redacted]	1137.05	420.00	500.00	Muscoy	80.00	Well head spigot	
EPA 109	EPA 109	EW-109	[redacted]	[redacted]	1137.05	550.00	610.00	Muscoy	60.00	Well head spigot	
EPA 109	EPA 109	EW-109	[redacted]	[redacted]	1137.05	710.00	840.00	Muscoy	130.00	Well head spigot	
EPA 109PA	EPA 109PA	EW-109PZA	[redacted]	[redacted]	1137.05	310.00	330.00	Muscoy	20.00	Piezometer	
EPA 109PB	EPA 109PB	EW-109PZB	[redacted]	[redacted]	1137.05	430.00	450.00	Muscoy	20.00	Piezometer	
EPA 109PC	EPA 109PC	EW-109PZC	[redacted]	[redacted]	1137.05	800.00	820.00	Unknown	20.00	Piezometer	
EPA 110	EPA 110	EW-110	[redacted]	[redacted]	1149.30	225.00	270.00	Muscoy	45.00	Well head spigot	
EPA 110	EPA 110	EW-110	[redacted]	[redacted]	1149.30	305.00	650.00	Muscoy	345.00	Well head spigot	
EPA 110	EPA 110	EW-110	[redacted]	[redacted]	1149.30	715.00	855.00	Muscoy	140.00	Well head spigot	
EPA 110PA	EPA 110PA	EW-110PZA	[redacted]	[redacted]	1145.50	193.00	243.50	Muscoy	50.50	Piezometer	
EPA 110PB	EPA 110PB	EW-110PZB	[redacted]	[redacted]	1145.48	301.00	321.50	Muscoy	20.50	Piezometer	
EPA 110PC	EPA 110PC	EW-110PZC	[redacted]	[redacted]	1145.51	411.00	431.50	Muscoy	20.50	Piezometer	
EPA 110PD	EPA 110PD	EW-110PZD	[redacted]	[redacted]	1145.49	491.00	511.50	Muscoy	20.50	Piezometer	
EPA 110PE	EPA 110PE	EW-110PZE	[redacted]	[redacted]	1149.30	830.00	850.00	Muscoy	20.00	Piezometer	
EPA 111	EPA 111	EW-111	[redacted]	[redacted]	1169.51	235.00	265.00	Muscoy	30.00	Well head spigot	
EPA 111	EPA 111	EW-111	[redacted]	[redacted]	1169.51	305.00	660.00	Muscoy	355.00	Well head spigot	
EPA 111	EPA 111	EW-111	[redacted]	[redacted]	1169.51	765.00	1250.00	Muscoy	485.00	Well head spigot	
EPA 111PA	EPA 111PA	EW-111PZA	[redacted]	[redacted]	1165.68	193.50	243.50	Muscoy	50.00	Piezometer	
EPA 111PB	EPA 111PB	EW-111PZB	[redacted]	[redacted]	1165.69	375.50	395.50	Muscoy	20.00	Piezometer	
EPA 111PC	EPA 111PC	EW-111PZC	[redacted]	[redacted]	1165.70	456.00	476.00	Muscoy	20.00	Piezometer	
EPA 111PD	EPA 111PD	EW-111PZD	[redacted]	[redacted]	1169.49	780.00	800.00	Muscoy	20.00	Piezometer	
EPA 112	EPA 112	EW-112	[redacted]	[redacted]	1181.79	280.00	740.00	Muscoy	460.00	Well head spigot	
EPA 112	EPA 112	EW-112	[redacted]	[redacted]	1181.79	800.00	890.00	Muscoy	90.00	Well head spigot	
EPA 112PA	EW-112A	EW-112PA	[redacted]	[redacted]	1181.79	300.00	320.00	Muscoy	20.00	Piezometer	
EPA 112PB	EW-112B	EW-112PB	[redacted]	[redacted]	1181.79	660.00	680.00	Muscoy	20.00	Piezometer	
EPA 001PA	EW-1PA	EW-1PA	[redacted]	[redacted]	1093.90	380.00	400.00	Newmark	20.00	Piezometer	

City Well Identification	Stantec Well Identification	EPA Well Identification	Easting	Northing	Elevation	Depth Sampled From (feet below ground surface [ft bgs])	Depth Sampled From (ft bgs)	Operable Unit Name	Screen Length (ft)	Sample Type	Passive Diffusion Bag (PDB) Sample Location (ft bgs)
EPA 001PB	EW-1PB	EW-1PB	[redacted]	[redacted]	1093.90	980.00	1000.00	Newmark	20.00	Piezometer	
EPA 002	EPA Well No. 2	EW-2	[redacted]	[redacted]	1091.70	500.00	1070.00	Newmark	570.00	Well head spigot	
EPA 002PA	EW-2PA	EW-2PA	[redacted]	[redacted]	1091.70	230.00	250.00	Newmark	20.00	Piezometer	
EPA 002PB	EW-2PB	EW-2PB	[redacted]	[redacted]	1091.70	880.00	900.00	Newmark	20.00	Piezometer	
EPA 003	EPA Well No. 3	EW-3	[redacted]	[redacted]	1090.22	240.00	280.00	Newmark	40.00	Well head spigot	
EPA 003	EPA Well No. 3	EW-3	[redacted]	[redacted]	1090.22	320.00	400.00	Newmark	80.00	Well head spigot	
EPA 003	EPA Well No. 3	EW-3	[redacted]	[redacted]	1090.22	500.00	800.00	Newmark	300.00	Well head spigot	
EPA 003PA	EW-3PA	EW-3PA	[redacted]	[redacted]	1090.22	230.00	250.00	Newmark	20.00	Piezometer	
EPA 003PB	EW-3PB	EW-3PB	[redacted]	[redacted]	1090.22	760.00	780.00	Newmark	20.00	Piezometer	
EPA 004	EPA Well No. 4	EW-4	[redacted]	[redacted]	1086.27	490.00	1180.00	Newmark	690.00	Well head spigot	
EPA 004PA	EW-4PA	EW-4PA	[redacted]	[redacted]	1086.27	310.00	330.00	Newmark	20.00	Piezometer	
EPA 004PB	EW-4PB	EW-4PB	[redacted]	[redacted]	1086.27	980.00	1000.00	Newmark	20.00	Piezometer	
EPA 005	EPA Well No. 5	EW-5	[redacted]	[redacted]	1083.27	400.00	1130.00	Newmark	730.00	Well head spigot	
EPA 005PA	EW-5PA	EW-5PA	[redacted]	[redacted]	1083.27	230.00	250.00	Newmark	20.00	Piezometer	
EPA 005PB	EW-5PB	EW-5PB	[redacted]	[redacted]	1083.27	880.00	900.00	Newmark	20.00	Piezometer	
EPA 006	EPA Well No. 6	EW-6	[redacted]	[redacted]	1396.55	115.00	315.00	Newmark	200.00	Well head spigot	
EPA 006PA	EW-6PA	EW-6PA	[redacted]	[redacted]	1396.55	230.00	250.00	Newmark	20.00	Piezometer	
EPA 007	EPA Well No. 7	EW-7	[redacted]	[redacted]	1404.54	200.00	470.00	Newmark	270.00	Well head spigot	
EPA 007PA	EW-7PA	EW-7PA	[redacted]	[redacted]	1404.54	320.00	340.00	Newmark	20.00	Piezometer	
Devil Canyon 1	Devil Canyon Well No. 1	MUNI-01	[redacted]	[redacted]	1530.00	186.00	236.00	Newmark	50.00	Well head spigot	
DTSC 001B	Electric Dr. No. 01B	MUNI-07B	[redacted]	[redacted]	1311.07	236.00	246.00	Newmark	10.00	PDB	241
DTSC 001C	Electric Dr. No. 01C	MUNI-07C	[redacted]	[redacted]	1311.16	389.00	399.00	Newmark	10.00	PDB	394
DTSC 002B	Electric Dr. No. 02B	MUNI-09B	[redacted]	[redacted]	1307.84	252.00	262.00	Newmark	10.00	PDB	257
DTSC 002C	Electric Dr. No. 02C	MUNI-09C	[redacted]	[redacted]	1307.51	418.00	428.00	Newmark	10.00	PDB	423
Olive & Garner	Olive and Garner Well	MUNI-101	[redacted]	[redacted]	1130.00	350.00	1050.00	Muscoy	700.00	Well head spigot	
Baseline & California	Baseline and California	MUNI-102	[redacted]	[redacted]	1185.56	126.00	184.00	Muscoy	58.00	Well head spigot	
Baseline & California	Baseline and California	MUNI-102	[redacted]	[redacted]	1185.56	224.00	232.00	Muscoy	8.00	Well head spigot	

City Well Identification	Stantec Well Identification	EPA Well Identification	Easting	Northing	Elevation	Depth Sampled From (feet below ground surface [ft bgs])	Depth Sampled From (ft bgs)	Operable Unit Name	Screen Length (ft)	Sample Type	Passive Diffusion Bag (PDB) Sample Location (ft bgs)
Baseline & California	Baseline and California	MUNI-102	[redacted]	[redacted]	1185.56	262.00	304.00	Muscoy	42.00	Well head spigot	
Baseline & California	Baseline and California	MUNI-102	[redacted]	[redacted]	1185.56	312.00	372.00	Muscoy	60.00	Well head spigot	
Baseline & California	Baseline and California	MUNI-102	[redacted]	[redacted]	1185.56	468.00	476.00	Muscoy	8.00	Well head spigot	
Baseline & California	Baseline and California	MUNI-102	[redacted]	[redacted]	1185.56	540.00	560.00	Muscoy	20.00	Well head spigot	
MW State	State Street	MUNI-103	[redacted]	[redacted]	1214.58	60.00	128.00	Muscoy	68.00	PDB	94
MW State	State Street	MUNI-103	[redacted]	[redacted]	1214.58	248.00	345.00	Muscoy	97.00	PDB	296.5
19th #1	19th Street No. 1	MUNI-104A	[redacted]	[redacted]	1230.30	150.00	276.00	Muscoy	126.00	Well head spigot	
19th #1	MUNI-104A	MUNI-104A	[redacted]	[redacted]	1230.30	150.00	276.00	Muscoy	126.00	Well head spigot	
19th #1	19th Street No. 1	MUNI-104A	[redacted]	[redacted]	1230.30	322.00	356.00	Muscoy	34.00	Well head spigot	
19th #1	MUNI-104A	MUNI-104A	[redacted]	[redacted]	1230.30	322.00	356.00	Muscoy	34.00	Well head spigot	
19th #1	19th Street No. 1	MUNI-104A	[redacted]	[redacted]	1230.30	388.00	400.00	Muscoy	12.00	Well head spigot	
19th #1	MUNI-104A	MUNI-104A	[redacted]	[redacted]	1230.30	388.00	400.00	Muscoy	12.00	Well head spigot	
19th #1	19th Street No. 1	MUNI-104A	[redacted]	[redacted]	1230.30	470.00	512.00	Muscoy	42.00	Well head spigot	
19th #1	MUNI-104A	MUNI-104A	[redacted]	[redacted]	1230.30	470.00	512.00	Muscoy	42.00	Well head spigot	
19th #1	19th Street No. 1	MUNI-104A	[redacted]	[redacted]	1230.30	554.00	563.00	Muscoy	9.00	Well head spigot	
19th #1	MUNI-104A	MUNI-104A	[redacted]	[redacted]	1230.30	554.00	563.00	Muscoy	9.00	Well head spigot	
19th #1	19th Street No. 1	MUNI-104A	[redacted]	[redacted]	1230.30	575.00	611.00	Muscoy	36.00	Well head spigot	
19th #1	MUNI-104A	MUNI-104A	[redacted]	[redacted]	1230.30	575.00	611.00	Muscoy	36.00	Well head spigot	
19th #1	19th Street No. 1	MUNI-104A	[redacted]	[redacted]	1230.30	646.00	658.00	Muscoy	12.00	Well head spigot	
19th #1	MUNI-104A	MUNI-104A	[redacted]	[redacted]	1230.30	646.00	658.00	Muscoy	12.00	Well head spigot	
19th 2	19th Street No. 2	MUNI-104B	[redacted]	[redacted]	1236.25	185.00	355.00	Muscoy	170.00	Well head spigot	
19th 2	MUNI-104B	MUNI-104B	[redacted]	[redacted]	1236.25	185.00	355.00	Muscoy	170.00	Well head spigot	
19th 2	19th Street No. 2	MUNI-104B	[redacted]	[redacted]	1236.25	610.00	655.00	Muscoy	45.00	Well head spigot	
19th 2	MUNI-104B	MUNI-104B	[redacted]	[redacted]	1236.25	610.00	655.00	Muscoy	45.00	Well head spigot	
Colima	Colima	MUNI-107	[redacted]	[redacted]	1278.00	240.00	340.00	Muscoy	100.00	Multiple Screen	
Colima	Colima	MUNI-107	[redacted]	[redacted]	1278.00	418.00	442.00	Muscoy	24.00	Multiple Screen	
Mallory 3	Mallory No. 3	MUNI-108	[redacted]	[redacted]	1319.00	350.00	448.00	Muscoy	98.00	Well head spigot	

City Well Identification	Stantec Well Identification	EPA Well Identification	Easting	Northing	Elevation	Depth Sampled From (feet below ground surface [ft bgs])	Depth Sampled From (ft bgs)	Operable Unit Name	Screen Length (ft)	Sample Type	Passive Diffusion Bag (PDB) Sample Location (ft bgs)
Mallory 3	Mallory No. 3	MUNI-108	[redacted]		1319.00	478.00	484.00	Muscoy	6.00	Well head spigot	
Mallory 3	Mallory No. 3	MUNI-108	[redacted]		1319.00	510.00	628.00	Muscoy	118.00	Well head spigot	
MW PAPERBOARD	Paperboard	MUNI-109	[redacted]		1328.00	227.00	431.00	Muscoy	204.00	PDB	329
Cajon 3	Cajon # 3/State Well	MUNI-112	[redacted]		1894.00	150.00	347.00	Muscoy	197.00	Well head spigot	
DTSC 003A	DTSC 3A	MUNI-11A	[redacted]		1287.34	350.00	360.00	Newmark	10.00	PDB	355
DTSC 003C	DTSC 3C	MUNI-11C	[redacted]		1287.03	492.00	502.00	Newmark	10.00	PDB	497
Waterman	Waterman Avenue	MUNI-13	[redacted]		1244.40	258.00	267.00	Newmark	9.00	Well head spigot	
Waterman	Waterman Avenue	MUNI-13	[redacted]		1244.40	295.00	610.00	Newmark	315.00	Well head spigot	
31st & Mt. View	31st and Mt. View	MUNI-14	[redacted]		1233.01	325.00	553.00	Newmark	228.00	Well head spigot	
Leroy	Leroy Well	MUNI-16	[redacted]		1239.67	450.00	660.00	Newmark	210.00	Well head spigot	
27th & Acacia	27th Street and Acacia Street	MUNI-18	[redacted]		1184.07	243.00	259.00	Newmark	16.00	Well head spigot	
27th & Acacia	27th Street and Acacia Street	MUNI-18	[redacted]		1184.07	290.00	410.00	Newmark	120.00	Well head spigot	
27th & Acacia	27th Street and Acacia Street	MUNI-18	[redacted]		1184.07	442.00	456.00	Newmark	14.00	Well head spigot	
27th & Acacia	27th Street and Acacia Street	MUNI-18	[redacted]		1184.07	477.00	717.00	Newmark	240.00	Well head spigot	
17th & Sierra 1	17th Street Sw	MUNI-22	[redacted]		1141.90	494.00	571.50	Newmark	77.50	Well head spigot	
17th & Sierra 1	17th Street Sw	MUNI-22	[redacted]		1141.90	576.50	670.00	Newmark	93.50	Well head spigot	
16th & Sierra	16th Street and Sierra Way	MUNI-23	[redacted]		1135.27	490.00	680.00	Newmark	190.00	Well head spigot	
Gilbert	Gilbert Street	MUNI-24	[redacted]		1123.33	480.00	603.00	Newmark	123.00	Well head spigot	
Gilbert	Gilbert Street	MUNI-24	[redacted]		1123.33	625.00	685.00	Newmark	60.00	Well head spigot	
MW 001B	Newmark MW 1B	MW01B	[redacted]		1182.36	294.00	304.00	Newmark	10.00	Monitoring Well	
MW 001C	Newmark MW 1C	MW01C	[redacted]		1182.36	380.00	390.00	Newmark	10.00	Monitoring Well	
MW 001D	Newmark MW 1D	MW01D	[redacted]		1182.36	489.00	496.00	Newmark	7.00	Monitoring Well	
MW 001E	Newmark MW 1E	MW01E	[redacted]		1182.36	560.00	570.00	Newmark	10.00	Unknown	
MW 001F	Newmark MW 1F	MW01F	[redacted]		1182.36	642.00	652.00	Newmark	10.00	Unknown	
MW 002A	Newmark MW 2A	MW02A	[redacted]		1413.75	280.00	300.00	Newmark	20.00	PDB	290
MW 002B	Newmark MW 2B	MW02B	[redacted]		1413.75	370.00	390.00	Newmark	20.00	PDB	380
MW 003A	Newmark MW 3A	MW03A	[redacted]		1418.21	240.00	260.00	Newmark	20.00	PDB	250

City Well Identification	Stantec Well Identification	EPA Well Identification	Easting	Northing	Elevation	Depth Sampled From (feet below ground surface [ft bgs])	Depth Sampled From (ft bgs)	Operable Unit Name	Screen Length (ft)	Sample Type	Passive Diffusion Bag (PDB) Sample Location (ft bgs)
MW 003B	Newmark MW 3B	MW03B	[redacted]	[redacted]	1418.21	340.00	360.00	Newmark	20.00	PDB	350
MW 004A	Newmark MW 4A	MW04A	[redacted]	[redacted]	1410.72	265.00	275.00	Newmark	10.00	PDB	270
MW 004B	Newmark MW 4B	MW04B	[redacted]	[redacted]	1410.72	385.00	395.00	Newmark	10.00	PDB	390
MW 005A	Newmark MW 5A	MW05A	[redacted]	[redacted]	1403.58	278.00	298.00	Newmark	20.00	PDB	288
MW 005B	Newmark MW 5B	MW05B	[redacted]	[redacted]	1403.58	432.00	452.00	Newmark	20.00	PDB	442
MW 006A	Newmark MW 6A	MW06A	[redacted]	[redacted]	1435.88	250.00	270.00	Newmark	20.00	PDB	260
MW 006B	Newmark MW 6B	MW06B	[redacted]	[redacted]	1435.88	317.00	337.00	Newmark	20.00	PDB	327
MW 007A	Newmark MW 7A	MW07A	[redacted]	[redacted]	1436.03	305.00	325.00	Newmark	20.00	PDB	315
MW 007B	Newmark MW 7B	MW07B	[redacted]	[redacted]	1436.03	486.00	506.00	Newmark	20.00	PDB	496
MW 008A	Newmark MW 8A	MW08A	[redacted]	[redacted]	1475.07	275.00	295.00	Newmark	20.00	PDB	285
MW 008B	Newmark MW 8B	MW08B	[redacted]	[redacted]	1475.07	470.00	490.00	Newmark	20.00	PDB	480
MW 009A	Newmark MW 9A	MW09A	[redacted]	[redacted]	1377.81	265.00	285.00	Newmark	20.00	PDB	275
MW 009B	Newmark MW 9B	MW09B	[redacted]	[redacted]	1377.81	345.00	365.00	Newmark	20.00	PDB	355
MW 010A	Newmark MW 10A	MW10A	[redacted]	[redacted]	1127.42	350.00	380.00	Newmark	30.00	PDB	365
MW 010B	Newmark MW 10B	MW10B	[redacted]	[redacted]	1127.42	490.00	520.00	Newmark	30.00	PDB	505
MW 010C	Newmark MW 10C	MW10C	[redacted]	[redacted]	1127.42	750.00	780.00	Newmark	30.00	PDB	765
MW 011A	Newmark MW 11A	MW11A	[redacted]	[redacted]	1100.52	500.00	530.00	Newmark	30.00	PDB	515
MW 011B	Newmark MW 11B	MW11B	[redacted]	[redacted]	1100.52	770.00	800.00	Newmark	30.00	PDB	785
MW 011C	Newmark MW 11C	MW11C	[redacted]	[redacted]	1100.52	1070.00	1100.00	Newmark	30.00	PDB	1085
MW 126	MW-126	MW-126	[redacted]	[redacted]	1562.98	220.00	240.00	Source	20.00	PDB	230
MW 127A	Newmark MW 127A	MW-127A	[redacted]	[redacted]	1545.90	341.00	361.00	Source	20.00	PDB	351
MW 127A	MW-127A	MW-127A	[redacted]	[redacted]	1545.90	341.00	361.00	Source	20.00	PDB	351
MW 127B	Newmark MW 127B	MW-127B	[redacted]	[redacted]	1545.90	431.00	451.00	Source	20.00	PDB	441
MW 127B	MW-127B	MW-127B	[redacted]	[redacted]	1545.90	431.00	451.00	Source	20.00	PDB	441
MW 128A	Newmark MW 128A	MW-128A	[redacted]	[redacted]	1215.04	410.00	440.00	Muscoy	30.00	PDB	425
MW 128A	MW-128A	MW-128A	[redacted]	[redacted]	1215.04	410.00	440.00	Muscoy	30.00	PDB	425
MW 128B	Newmark MW 128B	MW-128B	[redacted]	[redacted]	1215.04	690.00	720.00	Muscoy	30.00	PDB	705

City Well Identification	Stantec Well Identification	EPA Well Identification	Easting	Northing	Elevation	Depth Sampled From (feet below ground surface [ft bgs])	Depth Sampled From (ft bgs)	Operable Unit Name	Screen Length (ft)	Sample Type	Passive Diffusion Bag (PDB) Sample Location (ft bgs)
MW 128B	MW-128B	MW-128B	[redacted]		1215.04	690.00	720.00	Muscoy	30.00	PDB	705
MW 128C	Newmark MW 128C	MW-128C			1215.04	860.00	890.00	Muscoy	30.00	PDB	875
MW 128C	MW-128C	MW-128C			1215.04	860.00	890.00	Muscoy	30.00	PDB	875
MW 129A	Newmark MW 129A	MW-129A			1199.32	443.00	473.00	Muscoy	30.00	PDB	458
MW 129A	MW-129A	MW-129A			1199.32	443.00	473.00	Muscoy	30.00	PDB	458
MW 129B	Newmark MW 129B	MW-129B			1198.91	730.00	760.00	Muscoy	30.00	PDB	745
MW 129B	MW-129B	MW-129B			1198.91	730.00	760.00	Muscoy	30.00	PDB	745
MW 129C	Newmark MW 129C	MW-129C			1198.92	851.00	881.00	Muscoy	30.00	PDB	866
MW 129C	MW-129C	MW-129C			1198.92	851.00	881.00	Muscoy	30.00	PDB	866
MW 012A	MW-12A	MW12A			1088.51	240.00	270.00	Newmark	30.00	PDB	255
MW 012B	MW-12B	MW12B			1088.51	670.00	700.00	Newmark	30.00	PDB	685
MW 012C	MW-12C	MW12C			1088.53	1040.00	1070.00	Newmark	30.00	PDB	1055
MW 130A	Newmark MW 130A	MW-130A			1175.22	340.00	370.00	Muscoy	30.00	PDB	355
MW 130B	Newmark MW 130B	MW-130B			1174.58	550.00	580.00	Muscoy	30.00	PDB	565
MW 130C	Newmark MW 130C	MW-130C			1174.56	890.00	920.00	Muscoy	30.00	PDB	905
MW MIA 001A	MW-131A	MW-131A			1546.75	300.00	340.00	Source	40.00	PDB	320
MW MIA 001B	MW-131B	MW-131B			1546.75	435.00	475.00	Source	40.00	PDB	455
MW MIA 001C	MW-131C	MW-131C			1546.75	515.00	555.00	Source	40.00	PDB	535
MW MIA 002A	MW-132A	MW-132A			1479.30	142.00	182.00	Source	40.00	PDB	181
MW MIA 002B	MW-132B	MW-132B			1478.94	370.00	410.00	Source	40.00	PDB	390
MW MIA 003A	MW-133A	MW-133A			1435.39	185.00	225.00	Source	40.00	PDB	205
MW MIA 003B	MW-133B	MW-133B			1435.39	280.00	320.00	Source	40.00	PDB	300
MW MIA 004	MW-134	MW-134			1428.44	140.00	180.00	Source	40.00	PDB	160
MW 135A	MW-135A	MW-135A			1111.28	360.00	380.00	Muscoy	20.00	PDB	370
MW 135B	MW-135B	MW-135B			1111.28	620.00	640.00	Muscoy	20.00	PDB	630
MW 135C	MW-135C	MW-135C			1111.30	850.00	870.00	Muscoy	20.00	PDB	860
MW 136A	MW-136A	MW-136A			1121.67	420.00	440.00	Muscoy	20.00	PDB	430

City Well Identification	Stantec Well Identification	EPA Well Identification	Easting	Northing	Elevation	Depth Sampled From (feet below ground surface [ft bgs])	Depth Sampled From (ft bgs)	Operable Unit Name	Screen Length (ft)	Sample Type	Passive Diffusion Bag (PDB) Sample Location (ft bgs)
MW 136B	MW-136B	MW-136B	[redacted]	[redacted]	1121.63	500.00	520.00	Muscoy	20.00	PDB	510
MW 136C	MW-136C	MW-136C	[redacted]	[redacted]	1121.61	730.00	750.00	Muscoy	20.00	PDB	740
MW 137A	MW-137A	MW-137A	[redacted]	[redacted]	1144.05	330.00	350.00	Muscoy	20.00	PDB	340
MW 137B	MW-137B	MW-137B	[redacted]	[redacted]	1144.10	520.00	540.00	Muscoy	20.00	PDB	530
MW 137C	MW-137C	MW-137C	[redacted]	[redacted]	1144.07	790.00	810.00	Muscoy	20.00	PDB	800
MW 138A	MW-138A	MW-138A	[redacted]	[redacted]	1156.87	320.00	340.00	Muscoy	20.00	PDB	330
MW 138B	MW-138B	MW-138B	[redacted]	[redacted]	1156.92	550.00	570.00	Muscoy	20.00	PDB	560
MW 138C	MW-138C	MW-138C	[redacted]	[redacted]	1156.99	960.00	980.00	Muscoy	20.00	PDB	970
MW 139A	MW-139A	MW-139A	[redacted]	[redacted]	1168.76	360.00	380.00	Muscoy	20.00	PDB	370
MW 139B	MW-139B	MW-139B	[redacted]	[redacted]	1168.71	540.00	560.00	Muscoy	20.00	PDB	550
MW 139C	MW-139C	MW-139C	[redacted]	[redacted]	1168.85	790.00	810.00	Muscoy	20.00	PDB	800
MW 013A	MW-13A	MW13A	[redacted]	[redacted]	1078.36	365.00	395.00	Newmark	30.00	PDB	380
MW 013B	MW-13B	MW13B	[redacted]	[redacted]	1078.36	525.00	555.00	Newmark	30.00	PDB	540
MW 013C	MW-13C	MW13C	[redacted]	[redacted]	1078.29	815.00	845.00	Newmark	30.00	PDB	830
MW 140A	MW-140A330	MW-140A	[redacted]	[redacted]	1305.25	300.00	400.00	Unknown	100.00	PDB	350
MW 140A	MW-140A	MW-140A	[redacted]	[redacted]	1305.25	300.00	400.00	Unknown	100.00	PDB	350
MW 140B	MW-140B	MW-140B	[redacted]	[redacted]	1305.25	530.00	560.00	Unknown	30.00	PDB	545
MW 140C	MW-140C	MW-140C	[redacted]	[redacted]	1305.25	690.00	720.00	Unknown	30.00	PDB	705
MW 141A	MW-141A	MW-141A	[redacted]	[redacted]	1122.78	310.00	340.00	Unknown	30.00	PDB	325
MW 014A	MW-14A	MW14A	[redacted]	[redacted]	1075.73	270.00	300.00	Newmark	30.00	PDB	285
MW 014B	MW-14B	MW14B	[redacted]	[redacted]	1075.73	570.00	600.00	Newmark	30.00	PDB	585
MW 014C	MW-14C	MW14C	[redacted]	[redacted]	1075.73	1060.00	1090.00	Newmark	30.00	PDB	1075
MW 015A	MW-15A	MW15A	[redacted]	[redacted]	1069.38	520.00	550.00	Newmark	30.00	PDB	535
MW 015B	MW-15B	MW15B	[redacted]	[redacted]	1069.38	690.00	720.00	Newmark	30.00	PDB	705
MW 015C	MW-15C	MW15C	[redacted]	[redacted]	1069.38	1020.00	1050.00	Newmark	30.00	PDB	1035
MW 016A	MW-16A	MW16A	[redacted]	[redacted]	1384.25	220.00	240.00	Newmark	20.00	PDB	230
MW 016B	MW-16B	MW16B	[redacted]	[redacted]	1384.25	430.00	450.00	Newmark	20.00	PDB	440

City Well Identification	Stantec Well Identification	EPA Well Identification	Easting	Northing	Elevation	Depth Sampled From (feet below ground surface [ft bgs])	Depth Sampled From (ft bgs)	Operable Unit Name	Screen Length (ft)	Sample Type	Passive Diffusion Bag (PDB) Sample Location (ft bgs)
MW 017A	MW-17A	MW17A	[redacted]		1392.63	270.00	290.00	Newmark	20.00	PDB	280
MW 017B	MW-17B	MW17B			1392.69	400.00	420.00	Newmark	20.00	PDB	410
MWCOE001A	MWCOE001A	MWCOE001A			1619.38	289.00	309.00	Source	20.00	PDB	299
MWCOE001B	MWCOE001B	MWCOE001B			1619.25	345.00	365.00	Source	20.00	PDB	357
MWCOE002	MWCOE002	MWCOE002			1669.47	330.00	350.00	Source	20.00	PDB	340
MWCOE003	MWCOE003	MWCOE003			1667.23	418.00	438.00	Source	20.00	PDB	428
MWCOE004	MWCOE004	MWCOE004			1713.00	100.00	120.00	Source	20.00	PDB	110
MWCOE005	MWCOE005	MWCOE005			1763.83	140.00	160.00	Source	20.00	PDB	150
MWCOE006	MWCOE006	MWCOE006			1745.00	98.00	118.00	Source	20.00	PDB	108
MWCOE007	MWCOE007	MWCOE007			1752.40	125.00	145.00	Source	20.00	PDB	135
MWCOE008	MWCOE008	MWCOE008			1697.30	135.00	155.00	Source	20.00	PDB	145
MWCOE009	MWCOE009	MWCOE009			1729.90	77.00	97.00	Source	20.00	PDB	87
PZ-124	PZ-124	PZ-124			1583.55	120.00	160.00	Source	40.00	PDB	140
PZ-125	PZ-125	PZ-125			1564.88	180.00	200.00	Source	20.00	PDB	190

Table 5.6 Treatment Systems Extraction Data

	19th St Plant Remedy (North)		Flow	Newmark Plant Remedy		Flow	Waterman Plant Remedy		Flow
Month/Year	Total Production (AF)	Total Pounds Removed	Weighted Removal lbs/AF	Total Production (AF)	Total Pounds Removed	Weighted Removal lbs/AF	Total Production (AF)	Total Pounds Removed	Weighted Removal lbs/AF
Mar-05	526.641	10.02	0.0190	261.379	3.83	0.0146	780.310	5.54	0.0071
Apr-05	1179.590	20.56	0.0174	284.332	3.99	0.0140	741.479	3.71	0.0050
May-05	1370.213	19.94	0.0146	378.195	4.05	0.0107	748.687	2.41	0.0032
Jun-05	703.500	12.91	0.0184	328.246	3.56	0.0109	758.205	2.16	0.0028
Jul-05	1125.711	15.01	0.0133	306.972	4.15	0.0135	802.755	4.38	0.0055
Aug-05	1354.735	20.48	0.0151	349.005	4.27	0.0122	797.992	3.89	0.0049
Sep-05	1330.196	22.41	0.0168	345.802	4.76	0.0138	798.056	1.96	0.0025
Oct-05	1334.578	23.57	0.0177	360.262	4.47	0.0124	815.696	5.33	0.0065
Nov-05	1239.761	19.45	0.0157	351.513	2.76	0.0078	811.847	5.01	0.0062
Dec-05	1367.357	18.57	0.0136	375.767	3.68	0.0098	871.412	4.66	0.0054
Jan-06	1360.179	20.60	0.0151	376.918	3.79	0.0100	853.536	5.39	0.0063
Feb-06	1249.941	16.13	0.0129	361.085	3.53	0.0098	817.960	4.62	0.0057
Mar-06	1257.872	17.14	0.0136	379.131	3.51	0.0093	874.410	5.13	0.0059
Apr-06	1288.17	16.00	0.0124	400.283	3.38	0.0084	851.182	4.71	0.0055
May-06	1366.465	17.63	0.0129	435.711	4.20	0.0096	876.095	4.85	0.0055
Jun-06	1333.912	17.26	0.0129	425.012	4.10	0.0096	841.198	4.84	0.0058
Jul-06	1346.364	16.71	0.0124	433.813	4.30	0.0099	857.952	5.02	0.0058
Aug-06	1320.573	15.18	0.0115	426.175	4.27	0.0100	857.849	4.73	0.0055
Sep-06	1263.285	16.72	0.0132	409.566	4.81	0.0117	725.759	4.50	0.0062
Oct-06	1170.591	15.44	0.0132	421.745	3.69	0.0087	800.647	5.09	0.0064
Nov-06	1099.184	9.71	0.0088	407.073	1.45	0.0036	790.483	4.18	0.0053
Dec-06	1288.18	4.86	0.0038	445.147	3.78	0.0085	669.224	4.30	0.0064
Jan-07	1160.809	4.71	0.0041	439.69	3.69	0.0084	556.272	4.26	0.0077
Feb-07	1027.94	5.31	0.0052	284.929	2.02	0.0071	618.726	4.15	0.0067
Mar-07	1134.635	5.96	0.0053	425.886	3.97	0.0093	796.880	7.11	0.0089
Apr-07	1236.061	7.50	0.0061	414.746	3.18	0.0077	844.244	7.75	0.0092
May-07	1303.962	16.15	0.0124	423.047	3.71	0.0088	926.371	7.56	0.0082
Jun-07	1234.705	12.28	0.0099	386.85	2.65	0.0069	888.447	5.10	0.0057
Jul-07	1247.576	16.70	0.0134	364.784	2.68	0.0073	911.059	6.03	0.0066
Aug-07	1196.708	16.10	0.0135	390.138	2.99	0.0077	918.493	7.38	0.0080
Sep-07	1160.869	14.98	0.0129	365.813	2.30	0.0063	874.470	6.26	0.0072
Oct-07	1201.224	14.83	0.0123	380.39	1.64	0.0043	904.197	6.54	0.0072
Nov-07	1158.232	19.86	0.0171	380.127	2.68	0.0071	871.739	6.56	0.0075
Dec-07	1086.846	10.29	0.0095	386.634	2.15	0.0056	912.807	5.19	0.0057
Jan-08	1251.618	18.28	0.0146	369.153	2.18	0.0059	862.521	5.66	0.0066
Feb-08	1246.021	12.40	0.0100	314.224	1.54	0.0049	683.120	4.56	0.0067
Mar-08	1368.833	14.40	0.0105	340.388	1.64	0.0048	859.636	5.33	0.0062
Apr-08	1138.817	11.94	0.0105	356.609	2.00	0.0056	920.709	3.74	0.0041
May-08	1230.998	12.47	0.0101	323.928	1.89	0.0058	969.649	5.75	0.0059
Jun-08	1138.817	11.94	0.0105	356.609	2.00	0.0056	832.032	3.74	0.0045
Jul-08	1168.110	16.06	0.0137	373.705	2.42	0.0065	836.883	4.40	0.0053
Aug-08	1212.969	15.98	0.0132	373.512	2.53	0.0068	844.617	6.75	0.0080
Sep-08	1176.878	10.06	0.0085	355.943	2.11	0.0059	796.329	4.99	0.0063
Oct-08	1211.374	12.87	0.0106	374.703	1.81	0.0048	872.983	5.82	0.0067
Nov-08	1169.583	9.62	0.0082	359.915	1.70	0.0047	856.208	5.48	0.0064
Dec-08	1096.498	4.78	0.0044	305.841	1.42	0.0046	896.283	4.80	0.0054
Jan-09	1167.055	7.19	0.0062	242.046	1.48	0.0061	884.645	5.57	0.0063
Feb-09	893.264	4.91	0.0055	218.521	1.45	0.0066	825.535	4.93	0.0060
Mar-09	874.569	6.43	0.0074	367.546	1.23	0.0033	892.312	4.87	0.0055
Apr-09	827.006	8.28	0.0100	365.85	1.42	0.0039	869.728	5.04	0.0058
May-09	1140.642	15.68	0.0137	378.577	2.16	0.0057	892.103	5.63	0.0063
Jun-09	1246.52	14.09	0.0113	362.085	2.07	0.0057	851.742	5.09	0.0060
Jul-09	1276.315	14.31	0.0112	370.131	2.13	0.0058	848.015	1.90	0.0022
Aug-09	1253.534	15.34	0.0122	369.327	2.00	0.0054	842.499	5.52	0.0066
Sep-09	1179.062	12.85	0.0109	348.861	1.54	0.0044	797.114	4.56	0.0057
Oct-09	1201.742	15.47	0.0129	357.155	1.20	0.0034	798.374	4.27	0.0053
Nov-09	1178.616	11.55	0.0098	332.323	1.87	0.0056	796.120	5.77	0.0072
Dec-09	921.602	7.35	0.0080	323.236	2.60	0.0080	790.517	7.46	0.0094
Jan-10	934.285	8.38	0.0090	312.878	1.55	0.0050	760.567	5.56	0.0073
Feb-10	899.984	10.42	0.0116	291.028	1.85	0.0064	523.719	4.75	0.0091
Mar-10	1049.733	10.52	0.0100	316.347	1.66	0.0052	644.096	3.66	0.0057
Apr-10	1033.517	11.20	0.0108	299.366	2.07	0.0069	656.474	5.16	0.0079
May-10	1073.770	12.53	0.0117	295.2	1.88	0.0064	669.300	4.89	0.0073
Jun-10	1016.988	7.86	0.0077	297.83	1.97	0.0066	735.247	4.49	0.0061
Jul-10	1060.703	11.87	0.0112	302.856	2.29	0.0076	830.882	5.46	0.0066
Aug-10	1041.387	13.31	0.0128	300.146	2.11	0.0070	822.036	5.17	0.0063
Sep-10	991.244	10.57	0.0107	291.527	1.34	0.0046	772.399	4.34	0.0056
Oct-10	1028.944	11.45	0.0111	269.96	1.82	0.0067	729.817	4.22	0.0058
Nov-10	946.736	9.32	0.0098	250.213	1.70	0.0068	598.676	5.10	0.0085
Dec-10	1006.850	9.32	0.0093	281.614	1.79	0.0064	713.555	5.23	0.0073
Jan-11	957.635	6.76	0.0071	291.374	1.36	0.0047	625.852	5.00	0.0080
Feb-11	802.305	5.06	0.0063	209.21	1.10	0.0053	559.965	4.54	0.0081
Mar-11	914.992	7.65	0.0084	188.419	0.85	0.0045	640.787	3.63	0.0057
Apr-11	961.730	9.62	0.0100	177.803	0.84	0.0047	609.141	4.70	0.0077
May-11	1047.394	13.93	0.0133	190.016	1.01	0.0053	624.926	5.32	0.0085
Jun-11	1028.264	11.61	0.0113	181.929	0.95	0.0052	595.157	3.25	0.0055
Jul-11	1046.550	13.31	0.0127	179.08	1.09	0.0061	590.135	4.73	0.0080
Aug-11	1065.608	10.81	0.0101	173.768	1.11	0.0064	677.193	5.64	0.0083
Sep-11	1024.064	12.00	0.0117	323.569	1.98	0.0061	739.478	5.48	0.0074
Oct-11	1066.948	11.54	0.0108	349.878	2.14	0.0061	685.994	6.15	0.0090
Nov-11	1046.995	11.22	0.0107	331.113	1.28	0.0039	638.479	3.77	0.0059
Dec-11	1028.172	12.20	0.0119	345.98	1.29	0.0037	676.972	3.24	0.0048
Jan-12	1078.548	11.27	0.0104	346.818	1.54	0.0044	671.618	3.62	0.0054
Feb-12	1017.008	11.28	0.0111	323.173	0.65	0.0020	641.235	5.58	0.0087
Mar-12	1055.606	8.03	0.0076	351.995	1.32	0.0038	736.926	6.73	0.0091
Apr-12	1006.309	6.58	0.0065	337.891	1.29	0.0038	748.364	5.54	0.0074
May-12	1036.194	11.60	0.0112	317.525	1.17	0.0037	774.250	5.69	0.0073
Jun-12	983.160	10.17	0.0103	329.707	1.84	0.0056	680.546	3.55	0.0052
Jul-12	987.105	9.66	0.0098	336.997	1.78	0.0053	689.015	4.01	0.0058
Aug-12	1038.652	11.60	0.0112	325.734	1.18	0.0036	735.300	4.03	0.0055
Sep-12	1077.658	9.97	0.0093	259.011	0.85	0.0033	639.301	3.35	0.0052
Oct-12	1099.564	10.18	0.0093	341.381	1.90	0.0056	565.480	5.11	0.0090
Nov-12	904.718	9.73	0.0108	334.115	1.55	0.0046	692.179	1.71	0.0025
Dec-12	955.055	10.34	0.0108	249.008	0.98	0.0039	624.938	5.10	0.0082

Table 6.1
MVS Grid and Kriging Parameters for Structural Geology Visualization

MVS Parameter	Value	Unit
No. of Points in Each Horizon	5,928	#
Easting (X) minimum	6,745,950	feet
Easting (X) maximum	6,784,450	feet
Easting (X) extent	38,500	feet
Easting (X) resolution	185	#
Avg. Easting (X) cell width	208	feet
Northing (Y) minimum	1,861,900	feet
Northing (Y) maximum	1,899,400	feet
Northing (Y) extent	37,500	feet
Northing (Y) resolution	188	#
Avg. Northing (Y) cell width	199	feet

Table 6.2
MVS Grid and Kriging Parameters for Aqueous Chemistry Visualizations

Analyte	PCE	Unit
Xmin	6745950	feet
Xmax	6784450	feet
X length	38500	feet
X resolution	185	#
X cell width	208	feet
Ymin	1861900	feet
Ymax	1899400	feet
Y length	37500	feet
Y resolution	188	#
Y cell length	199	feet
Z resolution	50	#
Adaptive gridding	Yes	N/A
Proportional gridding	Yes	N/A
Anisotropy ratio	10 to 1	Horizontal to vertical
Minimum screen interval	2.00	feet
Maximum screen interval	730.00	feet
Analyte minimum	0.5 (Non-detect)	ug/L
Max-gap	50.00	feet
Preclip minimum	0.10	ug/L
Preclip maximum	1.00E+09	ug/L
Postclip minimum	0.50	ug/L
Postclip maximum	1000000.00	ug/L
LT multiplier	1.00	#
Detection limit	0.50	ug/L
Analyte range	Annual maximum	N/A

Table 6.3
Effective Porosity vs. Earth Material (from McWorter and Sunada, 1977)

Porosity	Total Porosity, n		Effective Porosity, n_e	
Material	**Range**	**Arithmetic Mean**	**Range**	**Arithmetic Mean**
Sandstone (fine)	-	-	0.02 - 0.40	0.21
Sandstone (medium)	0.14 - 0.49	0.34	0.12 - 0.41	0.27
Siltstone	0.21 - 0.41	0.35	0.01 - 0.33	0.12
Sand (fine)	0.25 - 0.53	0.43	0.01 - 0.46	0.33
Sand (medium)	-	-	0.16 - 0.46	0.32
Sand (coarse)	0.31 - 0.46	0.39	0.18 - 0.43	0.30
Gravel (fine)	0.25 - 0.38	0.34	0.13 - 0.40	0.28
Gravel (medium)	-	-	0.17 - 0.44	0.24
Gravel (coarse)	0.24 - 0.36	0.28	0.13 - 0.25	0.21
Silt	0.34 - 0.51	0.45	0.01 - 0.39	0.20
Clay	0.34 - 0.57	0.42	0.01 - 0.18	0.06
Limestone	0.07 - 0.56	0.30	~0 - 0.36	0.14
Loess	-	-	0.14 - 0.22	0.18
Eolian sand	-	-	0.32 - 0.47	0.38
Tuff	-	-	0.02 - 0.47	0.21
Weathered granite	0.34 - 0.57	0.45	-	-
Weathered gabbro	0.42 - 0.45	0.43	-	-
Basalt	0.03 - 0.35	0.17	-	-
Schist	0.04 - 0.49	0.38	0.22 - 0.33	0.26

Table 6.4
Effective Porosities Applied to Source OU Lithologies

Source OU		
Lithology Designation	**Description**	**Effective Porosity, n_e**
2	Weathered Bedrock	0.35
3		0.03
4	Clay	0.06
5		0.11
6		0.15
7	Silt	0.20
8		0.23
9		0.26
10		0.29
11	Sand	0.32
12		0.30
13		0.28
14		0.26
15	Gravel	0.24

Table 7.1
List of 4-Dimensional Interactive Model Files

4-Dimensional Interactive Model File Names
NM1-Newmark geology.4d
NM2-Newmark lithology2.4d
NM3-Newmark water levelsrev.4d
NM4-1997 PCE plume.4d
NM5-PCE at 5 ppb from 1997-2012.4d
NM6-Highest PCE in Plume 1997-2012.4d
NM7-Lithology 2001 PCE water table fluctuations.4d
NM8-Water level changes point of divergence for NW source plume with clay.4d
NM9-Groundwater pathlines plus 1997 PCE plume and rel K_10-19-2012.4d
NM10-CJ10 ongoing source.4d

Table 11.1
Annual Combined Newmark and Muscoy OU System O&M Costs

Date Range	Total Cost (Rounded to the nearest $1,000)
April 2005 – December 2005	$1,200,000
January 2006 – December 2006	$2,200,000
January 2007 – October 2007	$2,000,000
November 2007 – December 2007	not available
January 2008 – December 2008	not available
January 2009 – December 2009	not available
January 2010 – May 2010	not available
July 2010 – June 2011	$1,900,000
July 2011 – June 2012	$1,400,000

Source: (EPA, 2013)

FIGURES

Figure 1.1. Newmark Groundwater Superfund Site, San Bernardino, California.

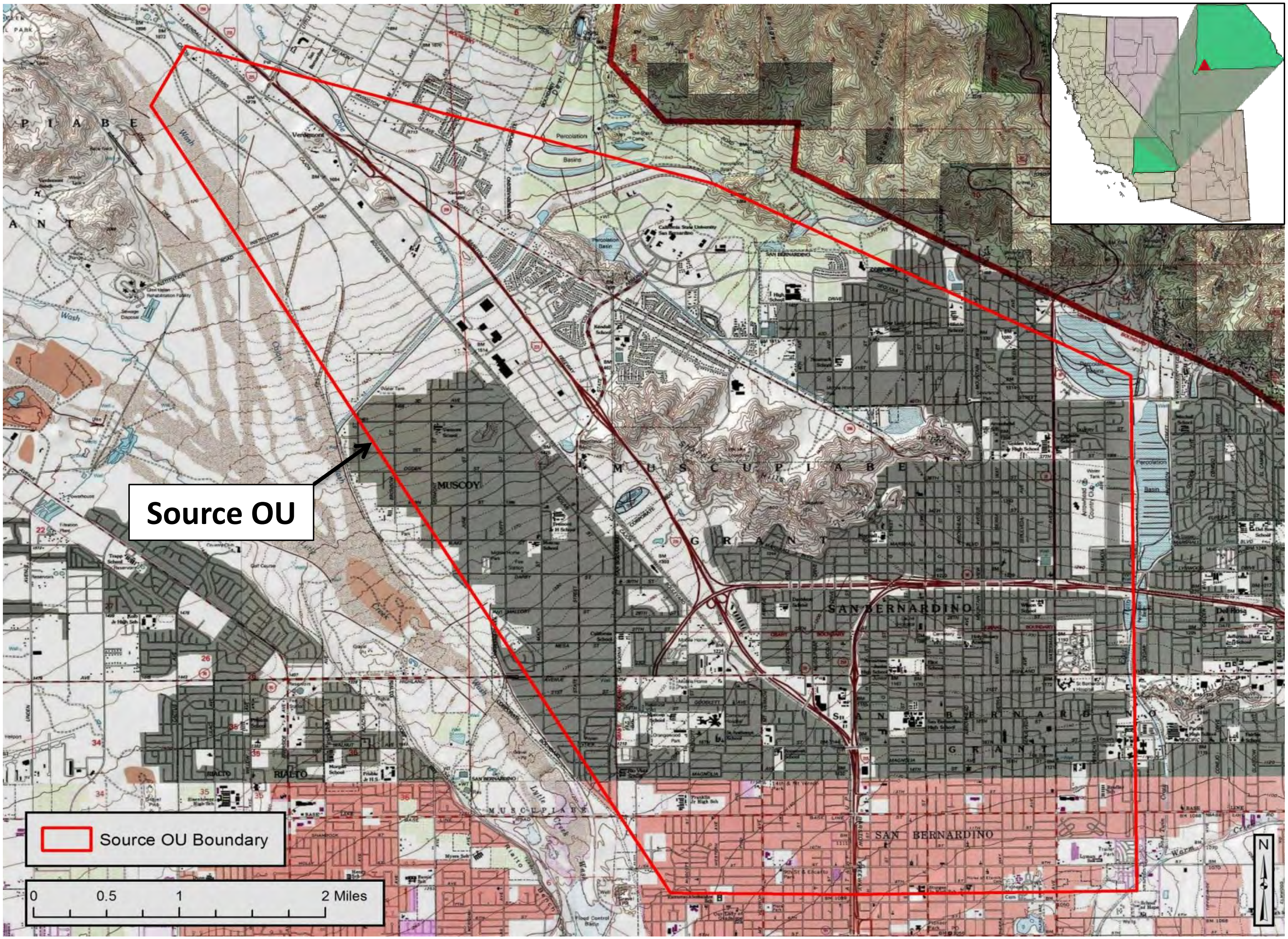


Figure 1.2. Newmark Groundwater Superfund Site Operable Units.

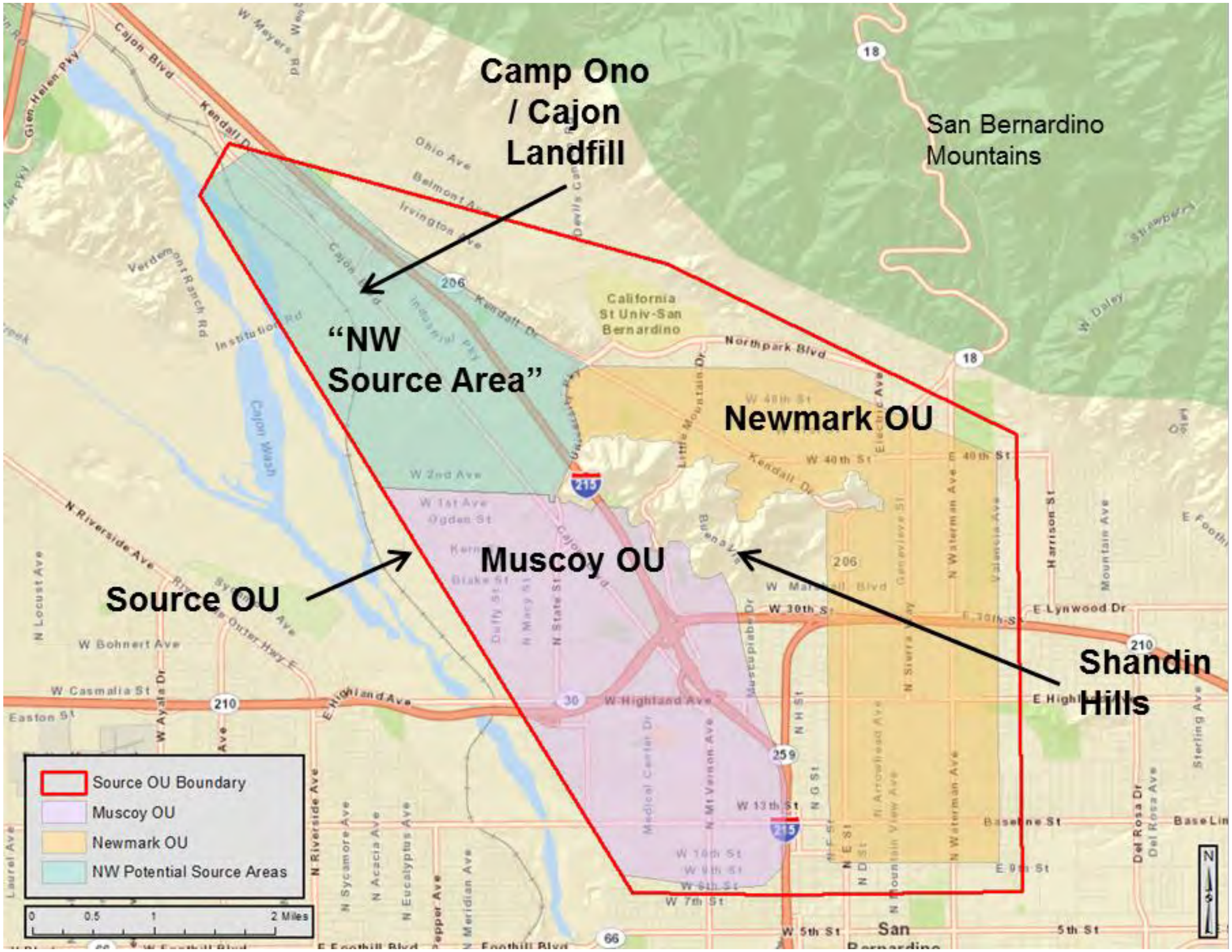


Figure 1.3. Locations of Newmark and Muscoy Plumes remedial investigation / feasibility study areas.

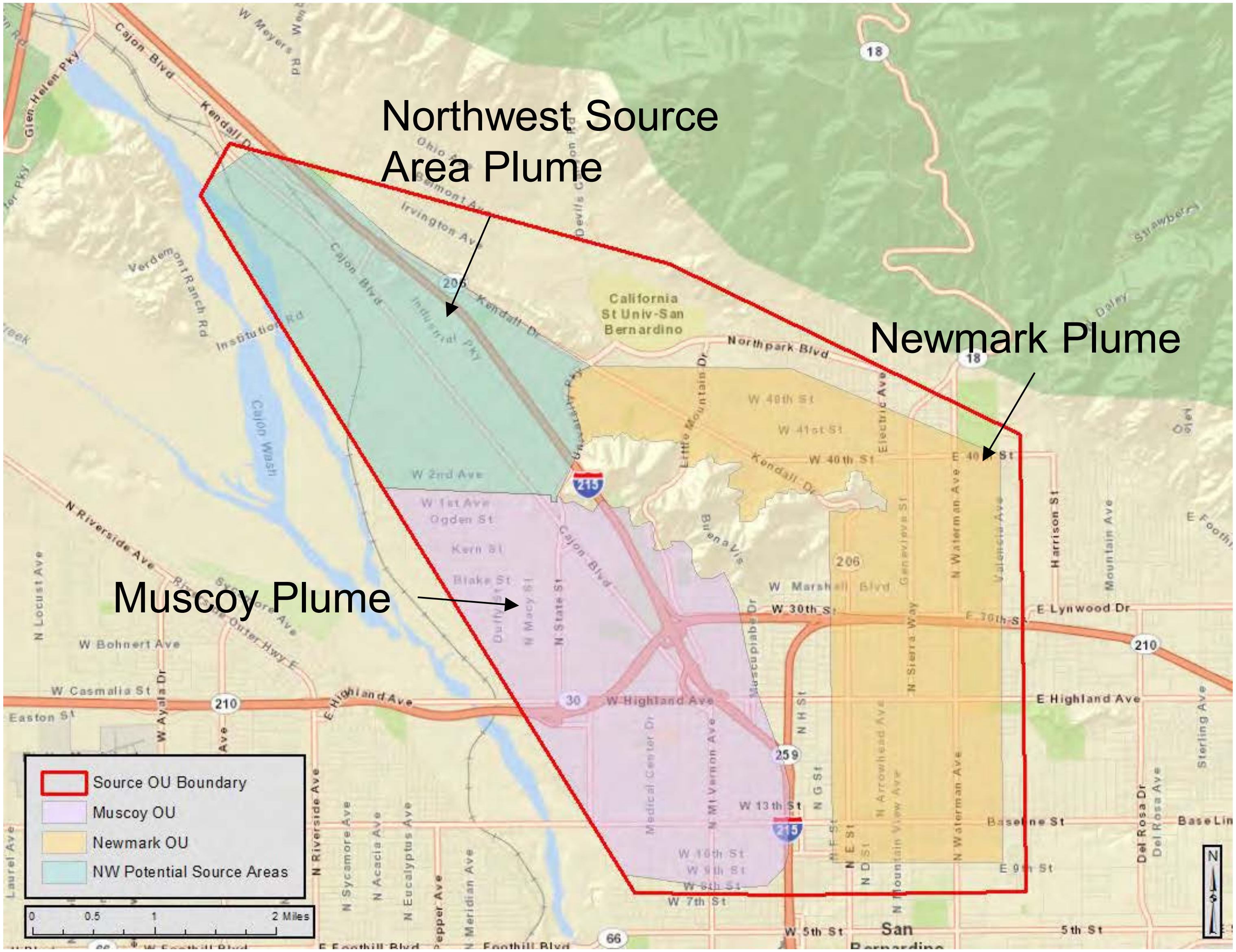


Figure 1.4. Source Operable Unit treatment systems extraction wells.

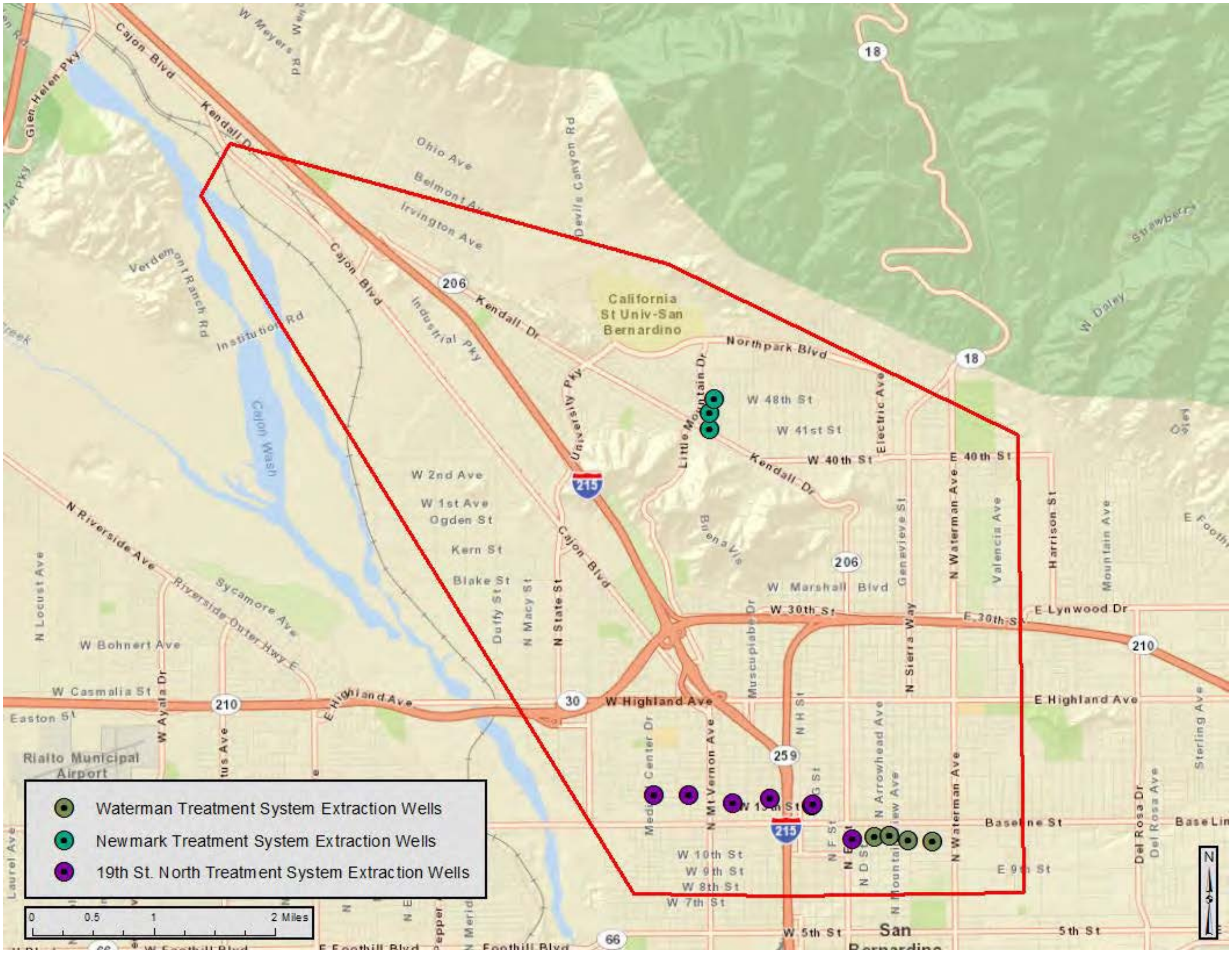
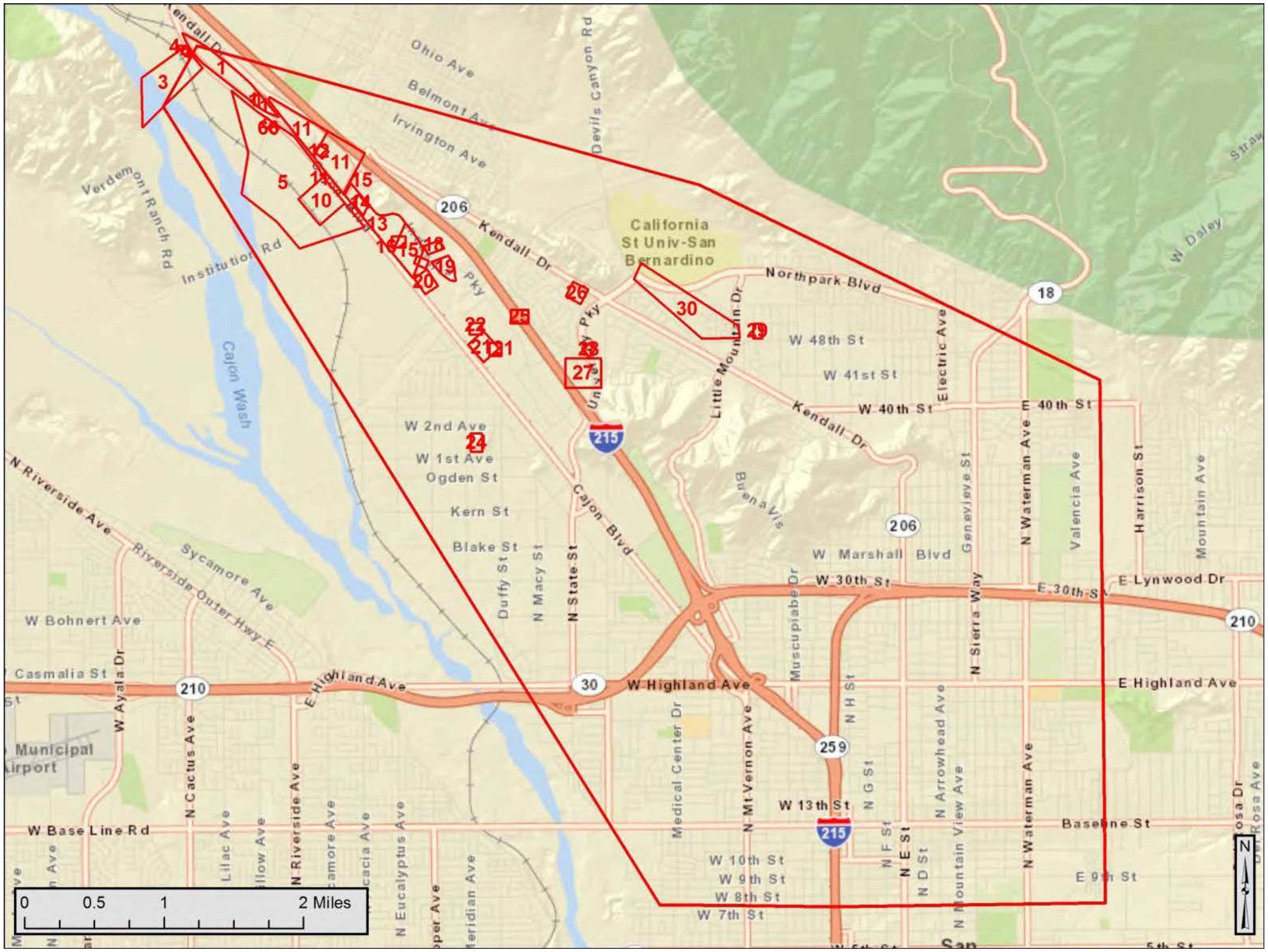


Figure 1.5. Potential contaminant sources in the NW Source Area and North of Shandin Hills.



Number	Name
1	Lozenge Parcel
2	Am-Mex Specialty Metals
3	Firing Range
4	Grand Central Investment LLC
5	Cajon Landfill Area
6	ANCO International, Inc.
10	Army Wastewater Treatment Plant
11	Apex Parcel
12	Former Steel Rolling Mill
13	Salvage Storage Yard
14	Fred G Walter and Son
15	3100 Area
16	Upper Motor Pool
17	Laundry Boiler Area
18	Jack's Disposal
19	Stockade Pits
20	3100 Area Trenches and Pit
21	Utilities Area
22	Vehicle Driver Training Center
23	Lower Motor Pool
24	Oil Change Ramp
25	Grease Pit
26	Engine Pit and Filling Station
27	Potential Grease/Wash Rack
28	Unnamed Area
29	"Cat Pit" Area
30	Former San Bernardino Airport

Figure 1.6. Timeline of regulatory actions, investigations and remedial efforts undertaken at the site from 1980 to 2010.

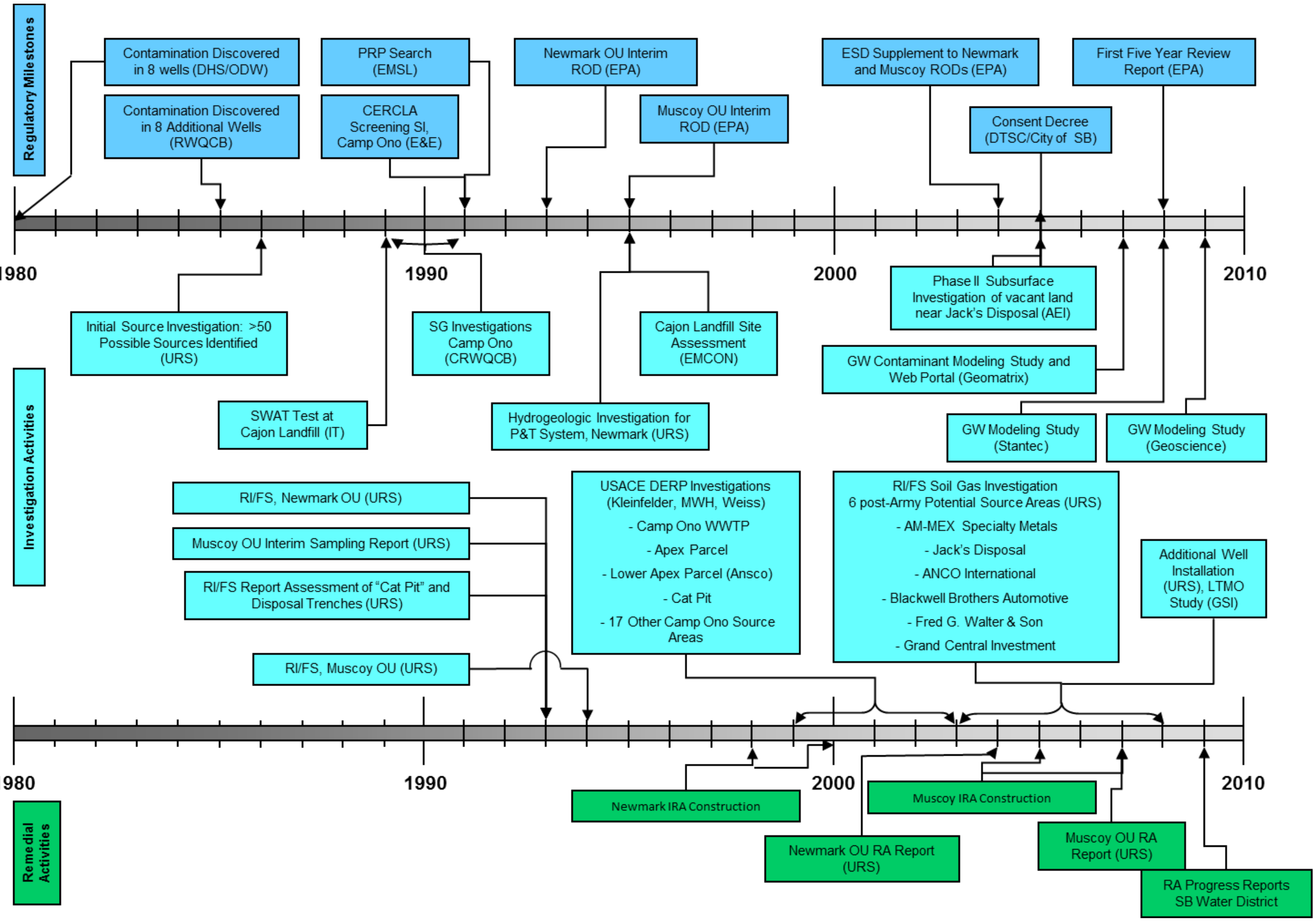


Figure 2.1. Regional topography.

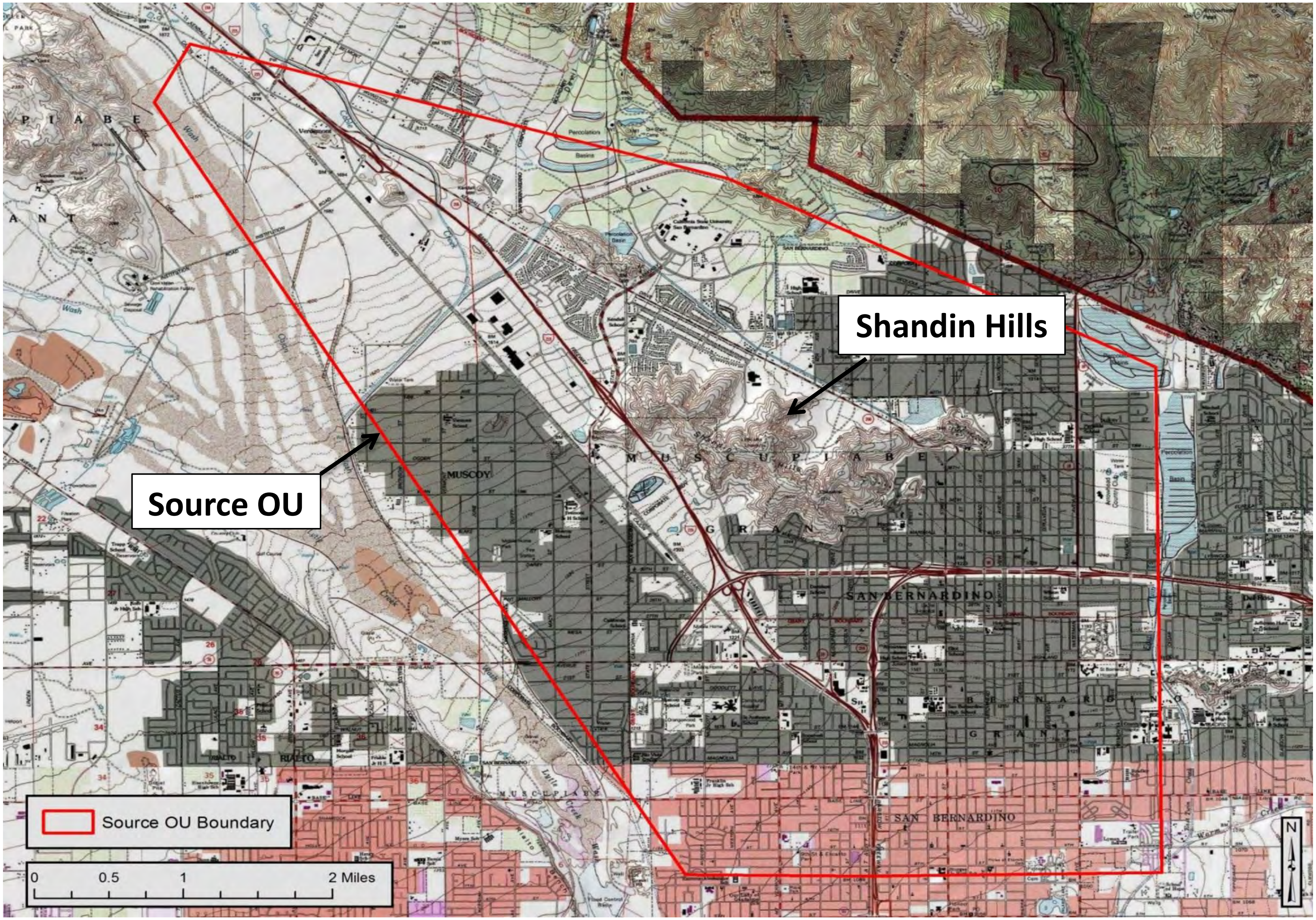


Figure 2.2. Regional geology and locations of primary bedrock outcroppings within the Source OU. Source: Stantec 2008.

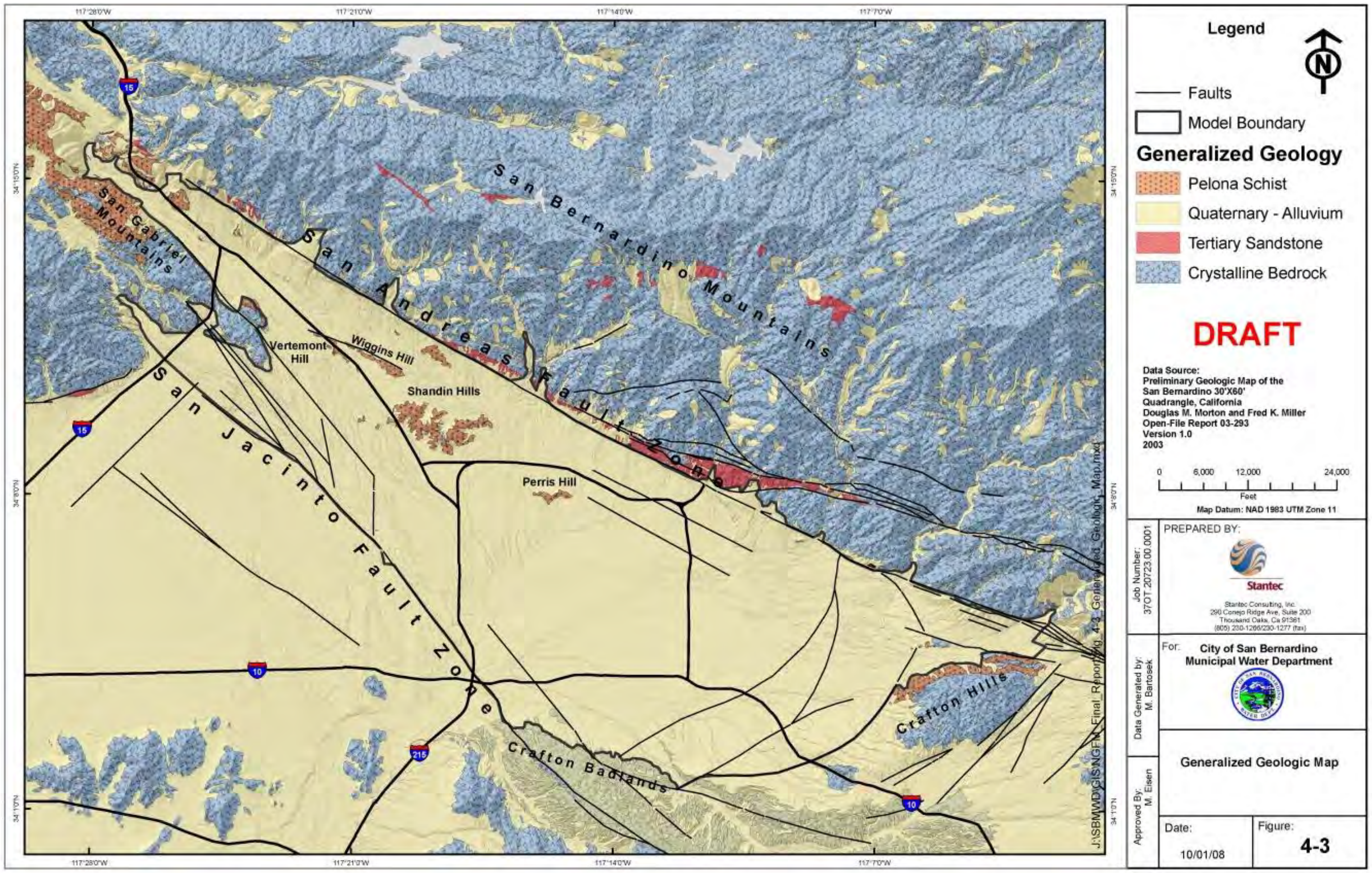


Figure 2.3. Average wind direction and speed in the San Bernardino, California area; March 1998 to July 2013. Source: Iowa State University Department of Agronomy (2013).

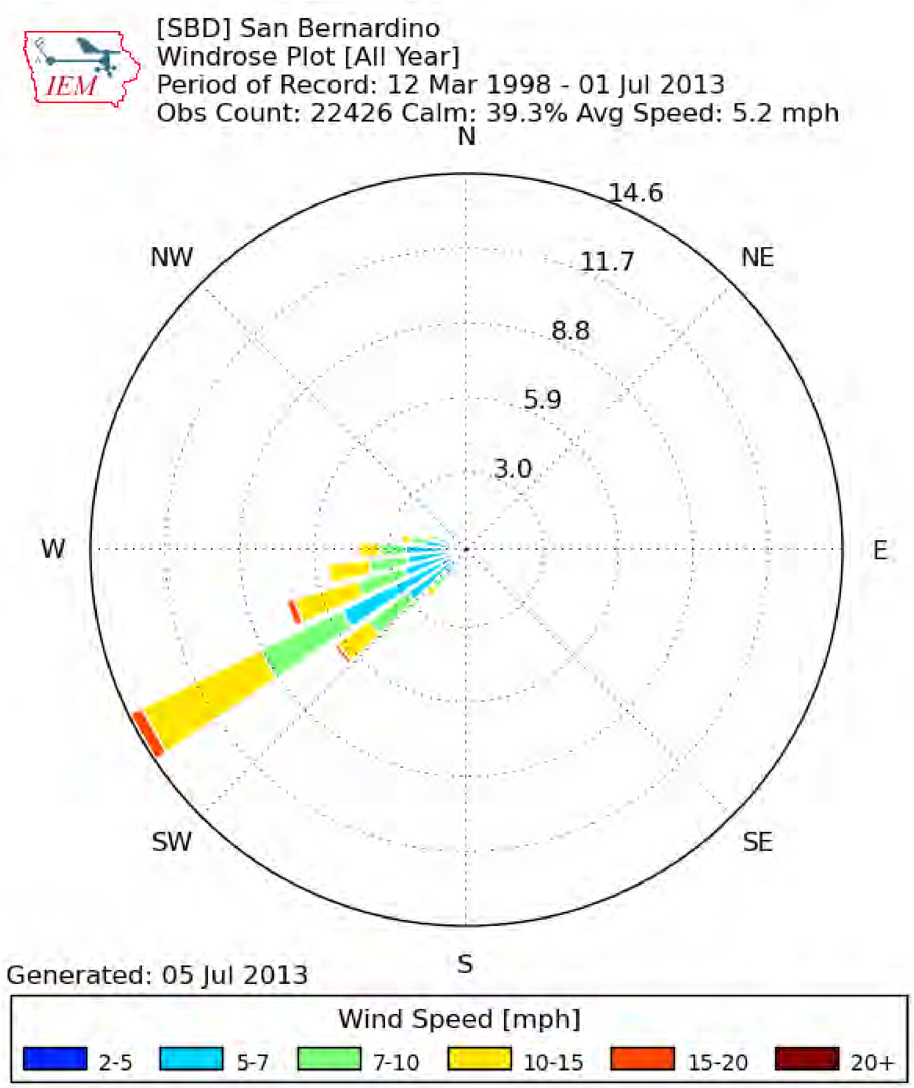


Figure 2.4. Hydrology of the San Bernardino, California area. Source: Geosciences 2009.

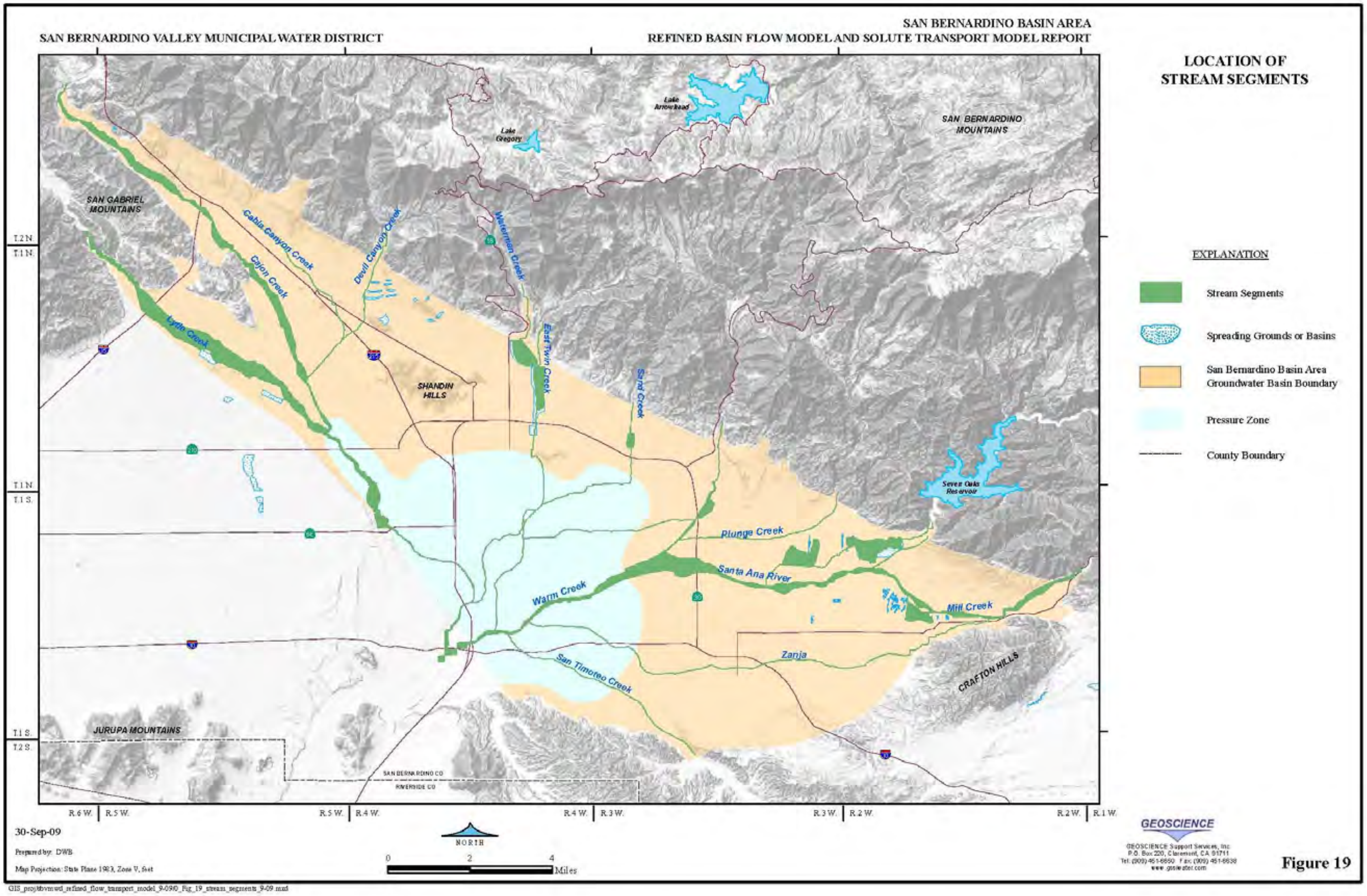


Figure 2.5. Structural geology of the San Bernardino, California area. Source: Stantec 2008.

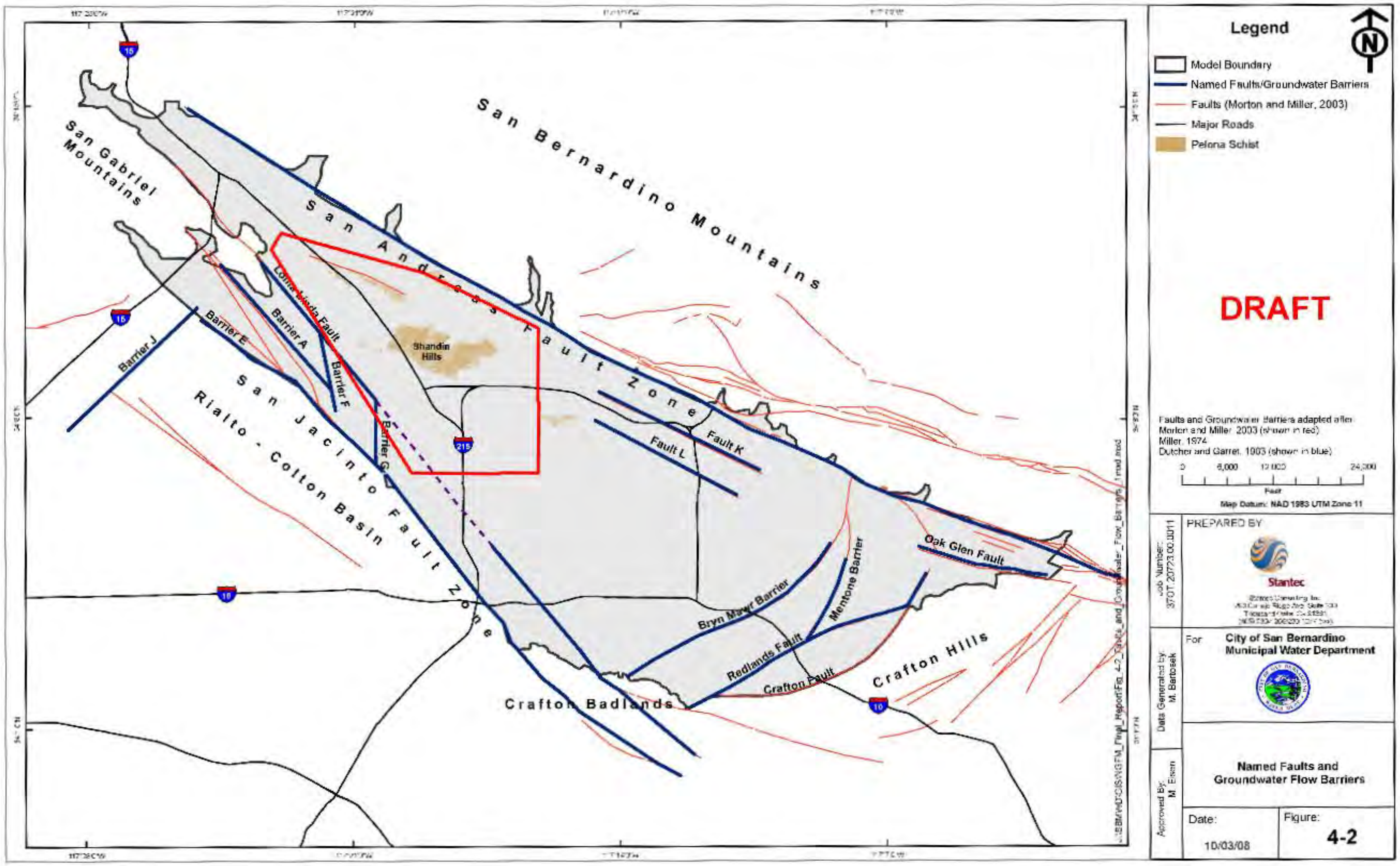


Figure 2.6. Groundwater flow direction in the alluvial aquifer in the San Bernardino, California area. Source: Stantec 2008.

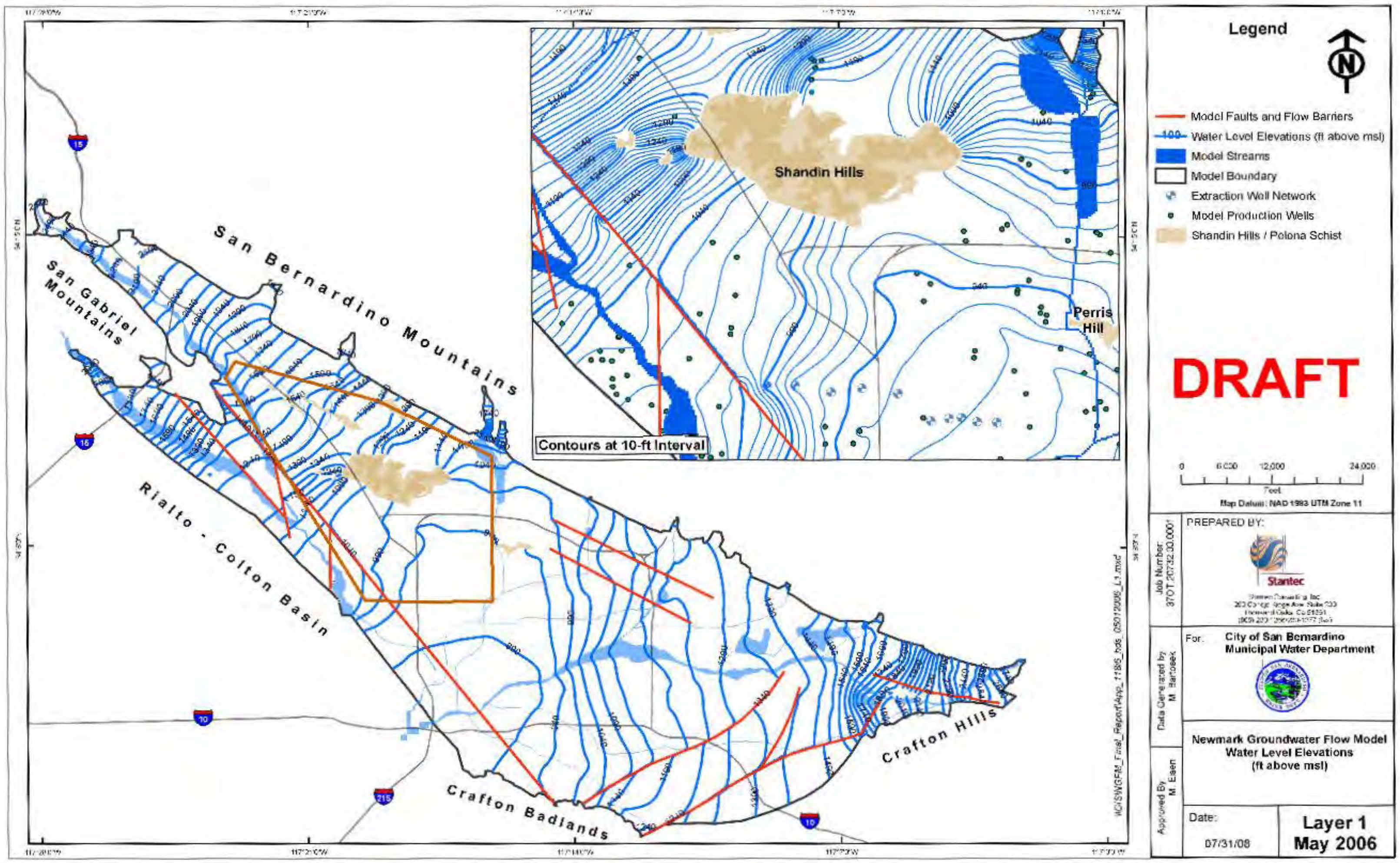


Figure 4.1. 3-Dimensional Visualization and Analysis (3DVA) Process Flow Chart

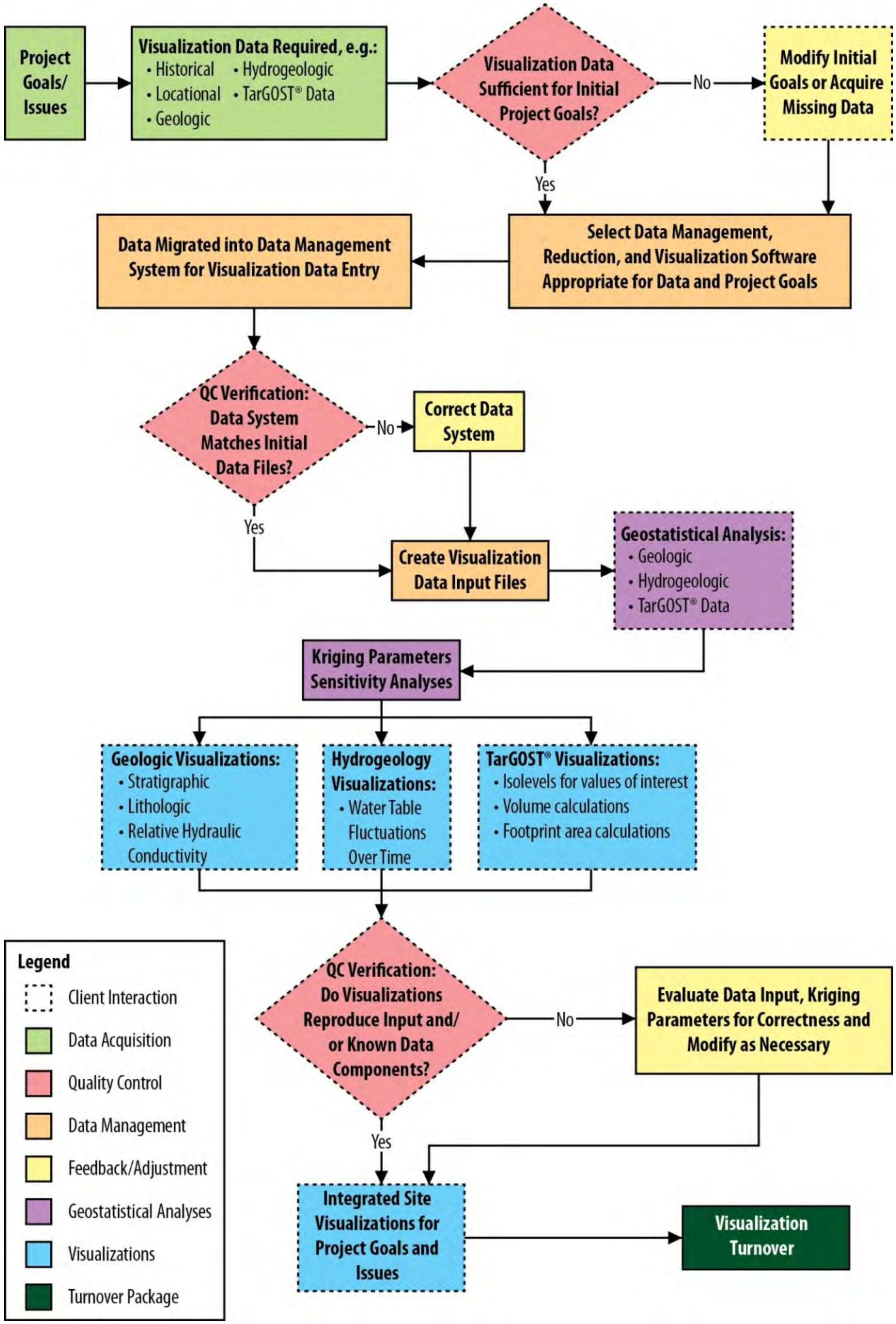


Figure 5.1. Locations of Camp Ono facilities from aerial photography.

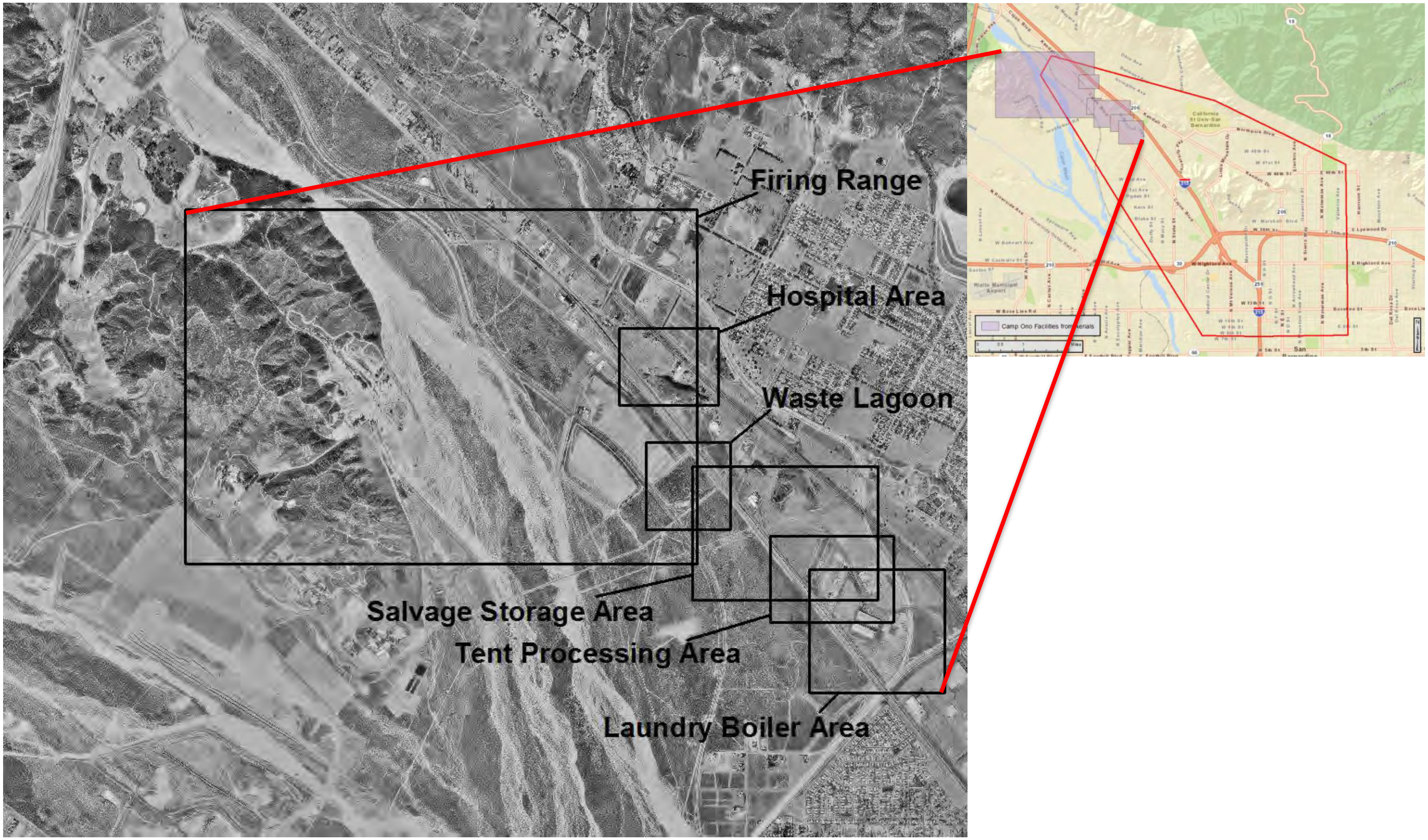


Figure 5.2. Locations of lithology boring logs used to construct the 3-D visualizations.

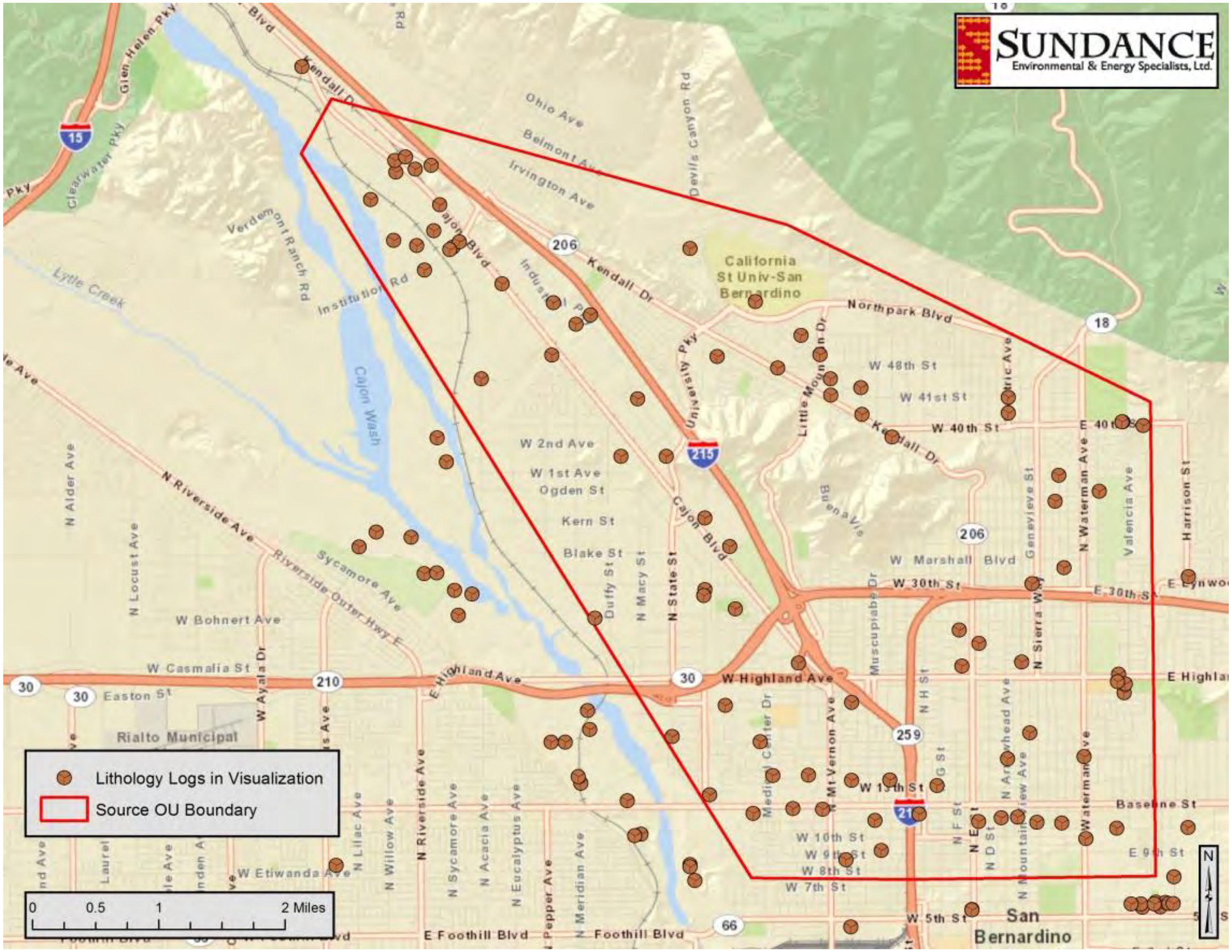


Figure 5.3. Locations of groundwater level observation wells used to construct the visualizations.

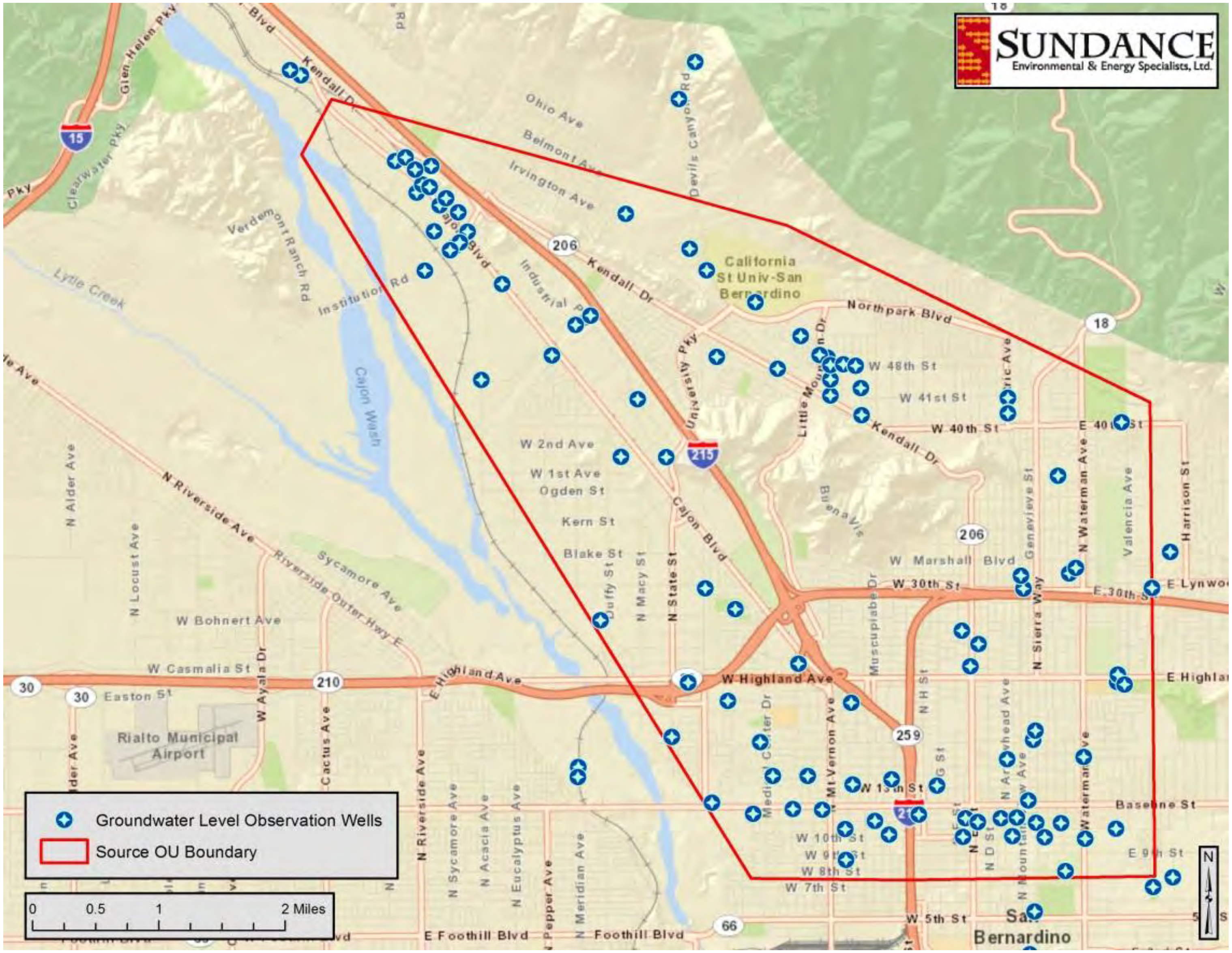


Figure 5.4. Locations of groundwater monitoring wells used to construct the visualizations.

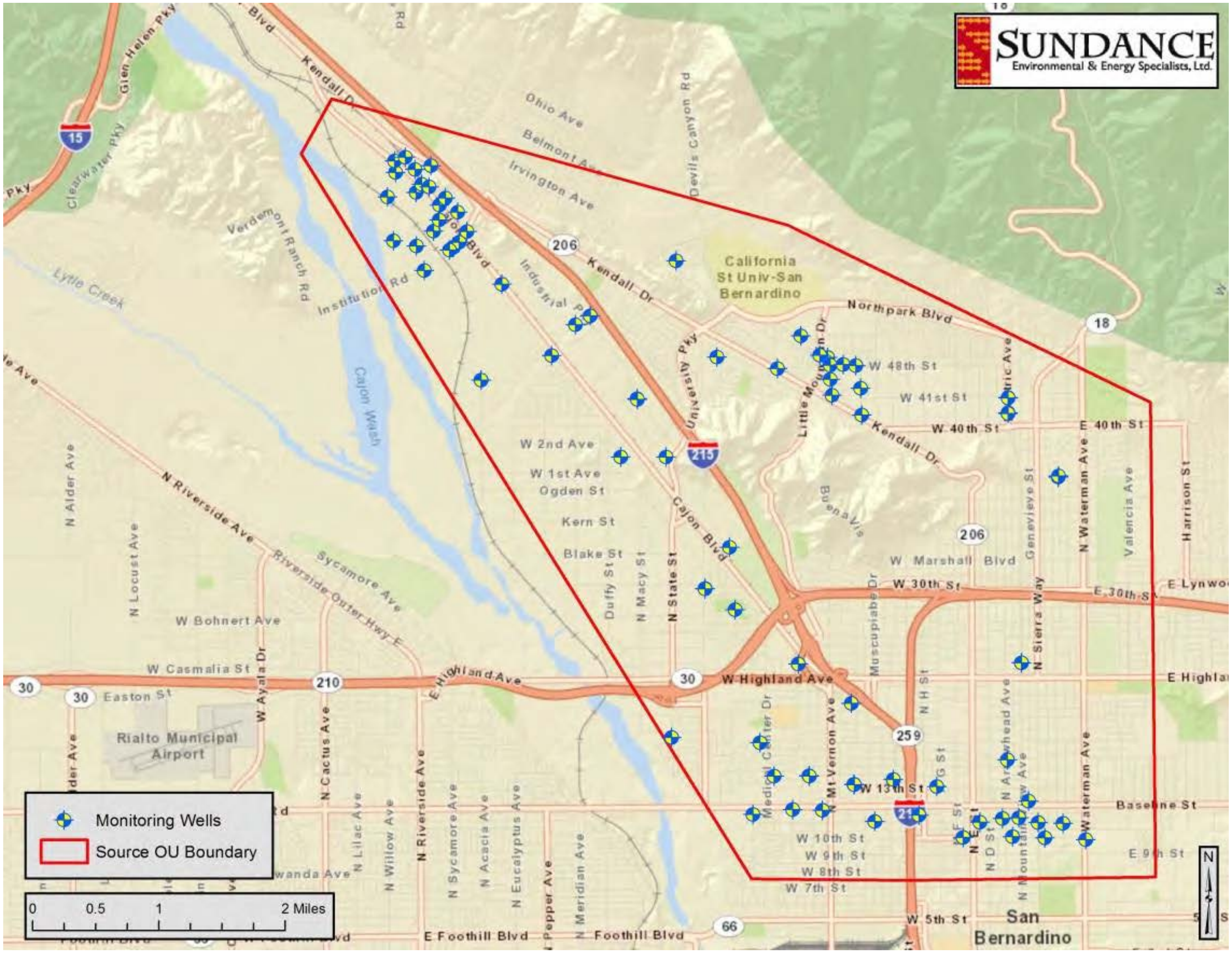


Figure 6.1. Framework of Source OU 3-D visualizations (Note: No vertical exaggeration).

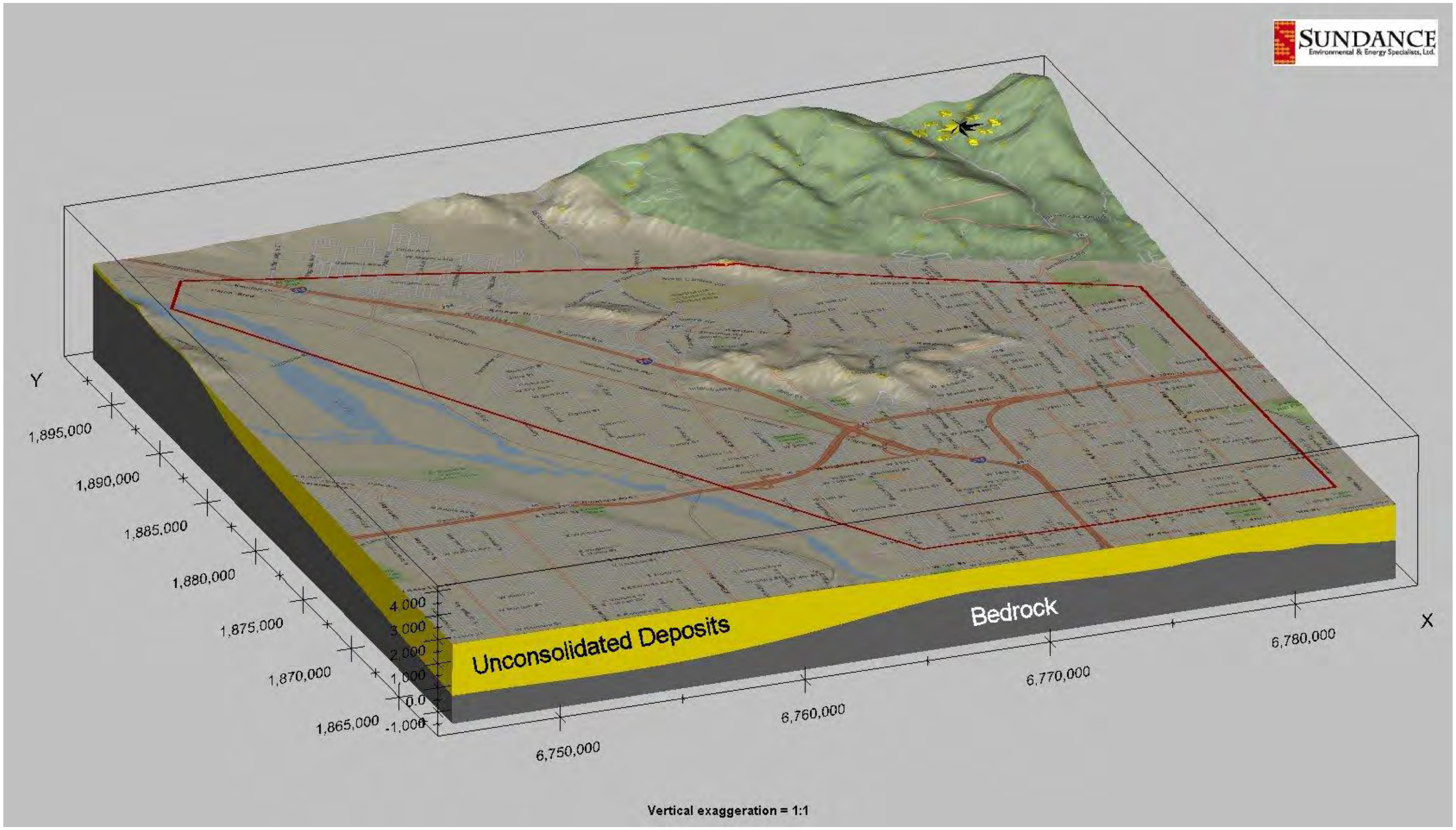


Figure 6.2. Lithology logs included in the EarthVision model of the San Bernardino area.

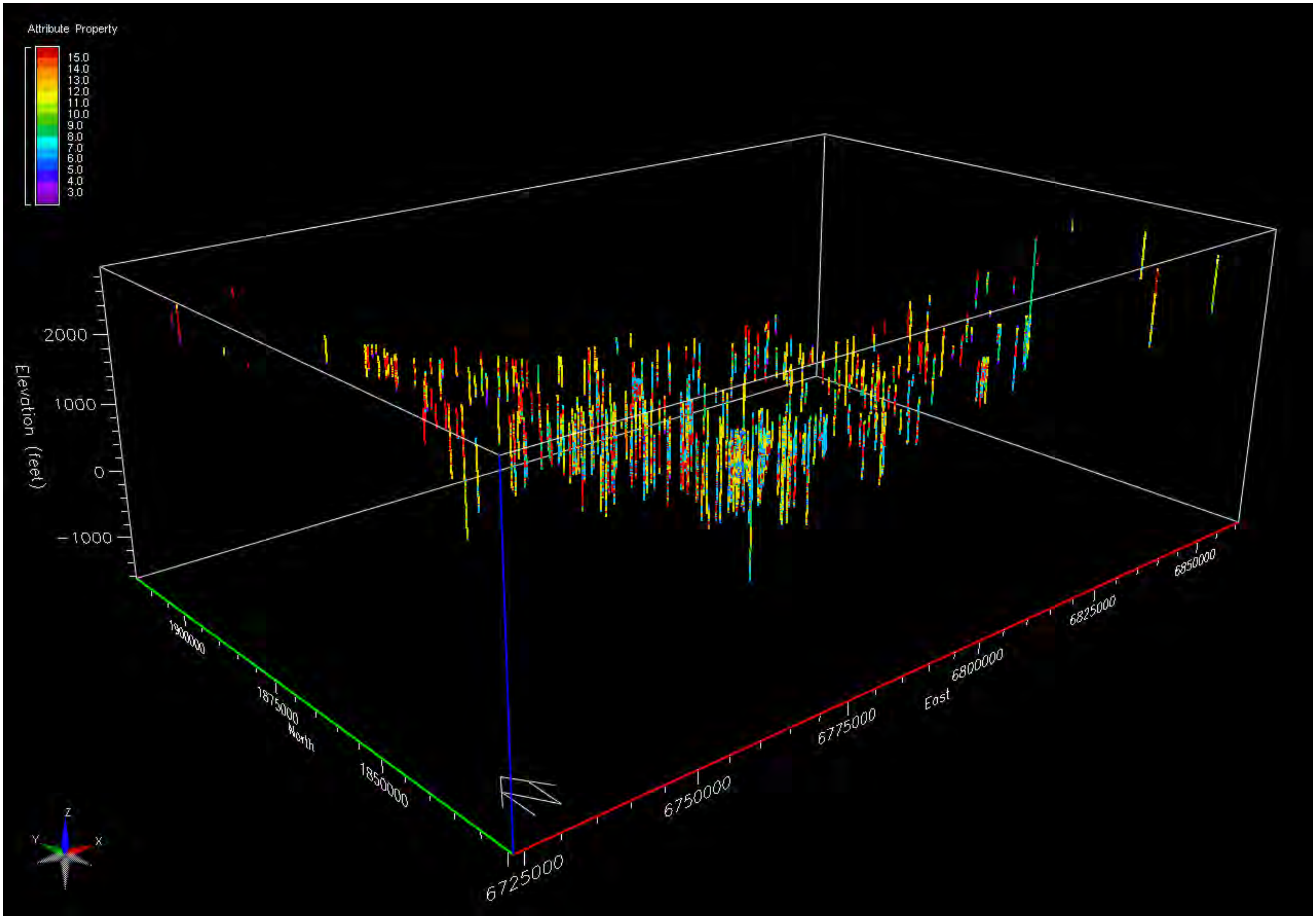


Figure 6.3 Distribution of lithology types in EarthVision lithology logs.

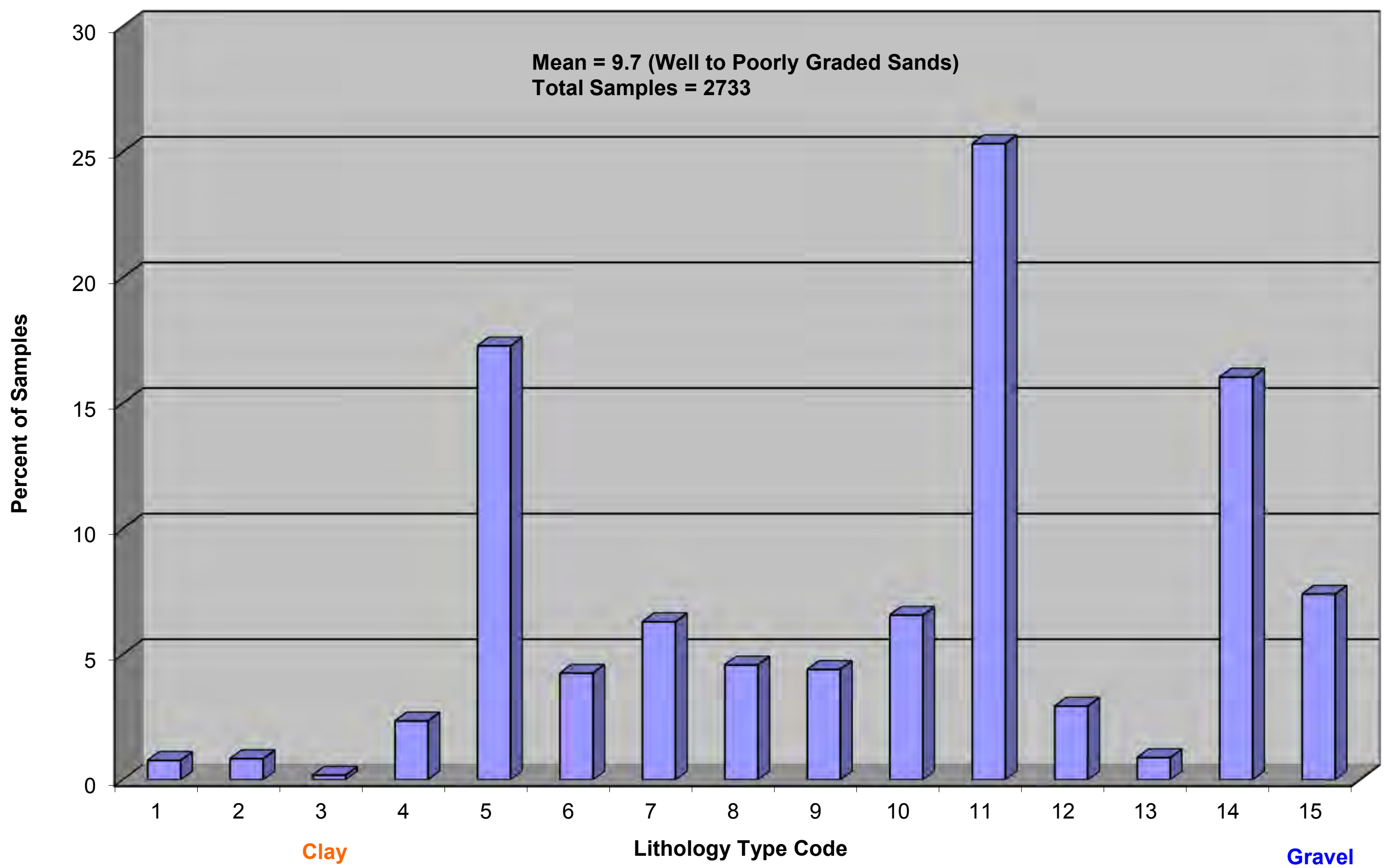


Figure 6.4. Max-gap sensitivity analysis for site-wide PCE.

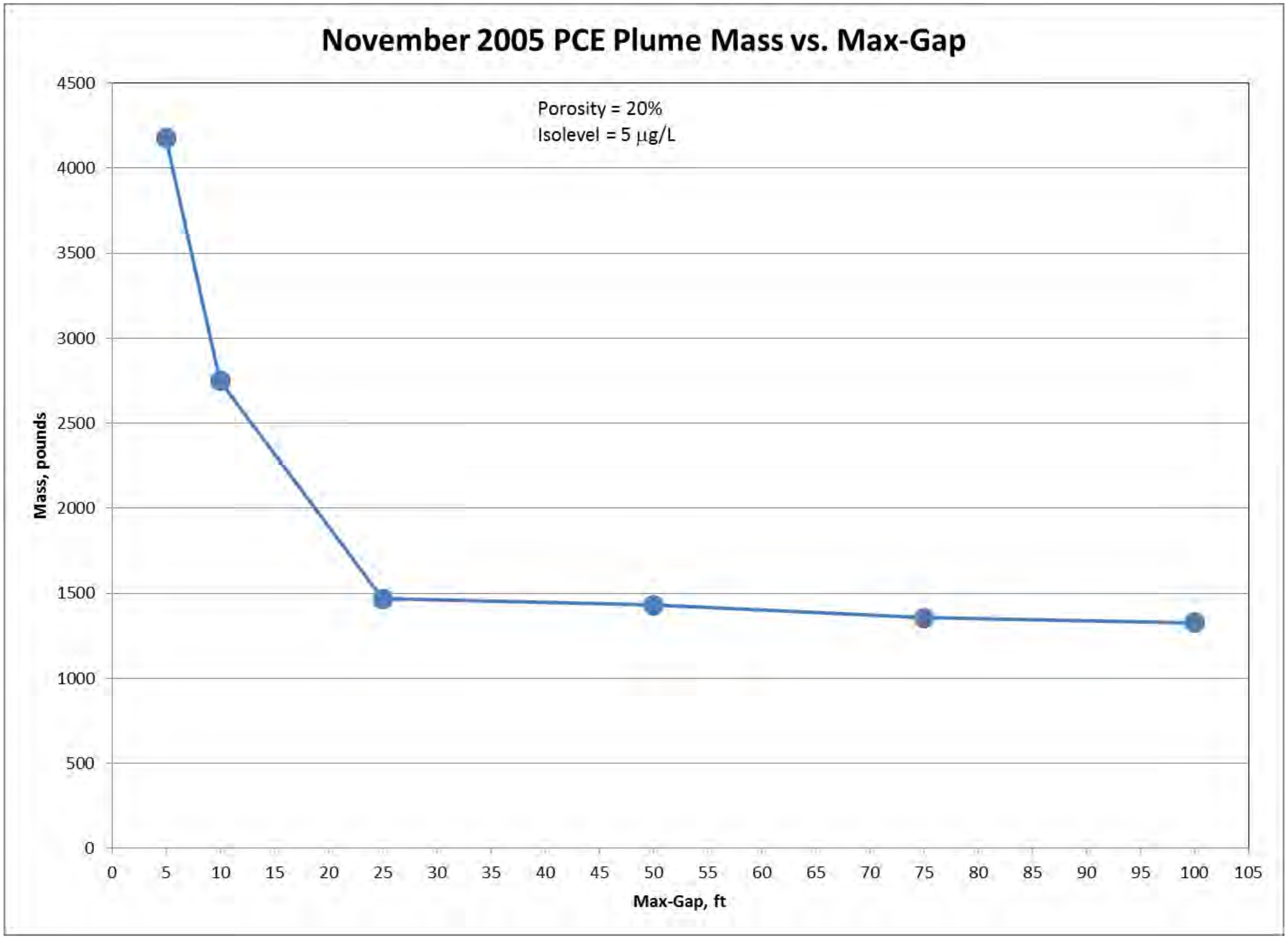


Figure 6.5. Example of PCE plume distribution at 3 µg/L.

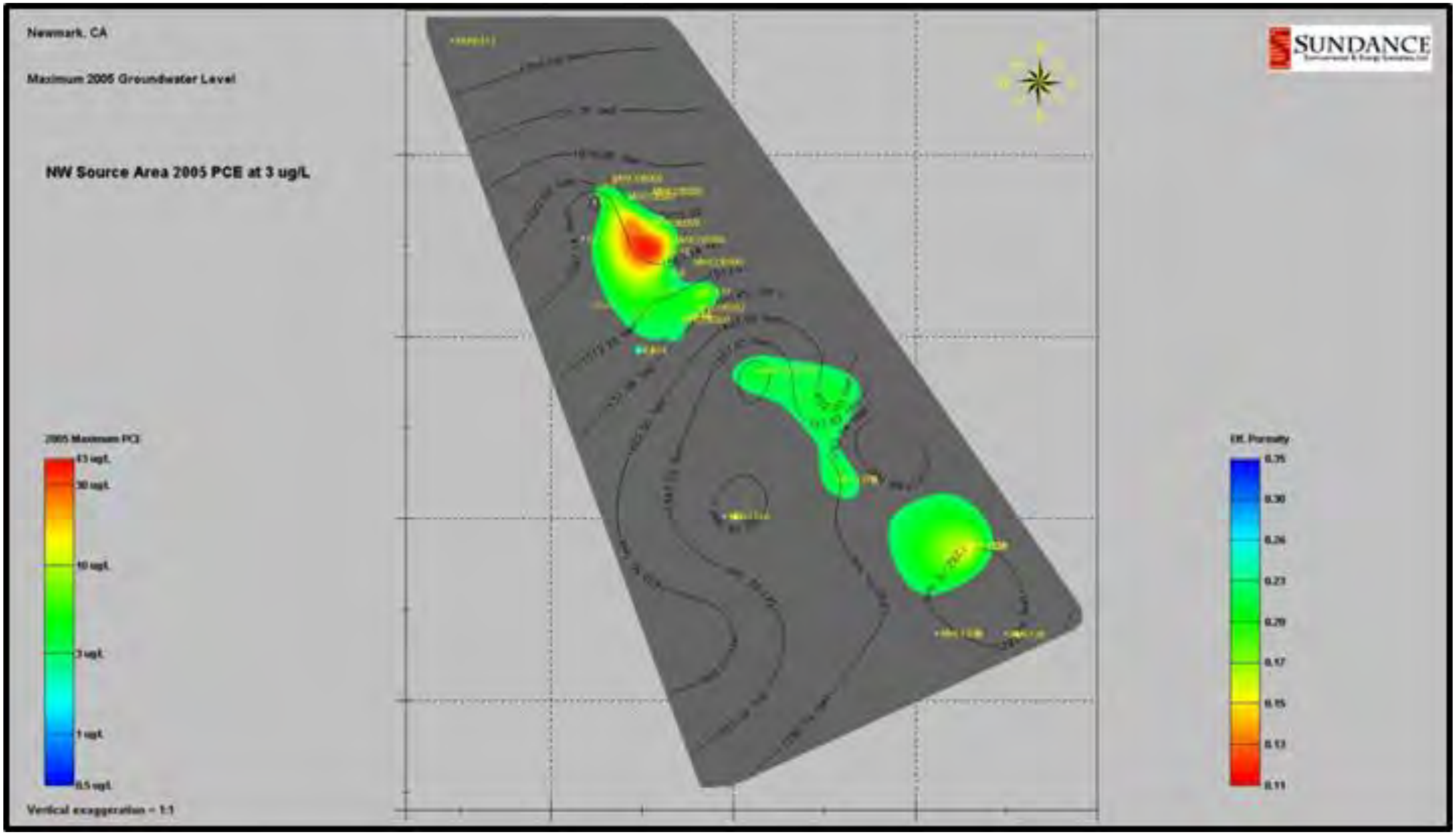


Figure 6.6. Estimated effective porosity within area of plume shown in Fig. 6.5.

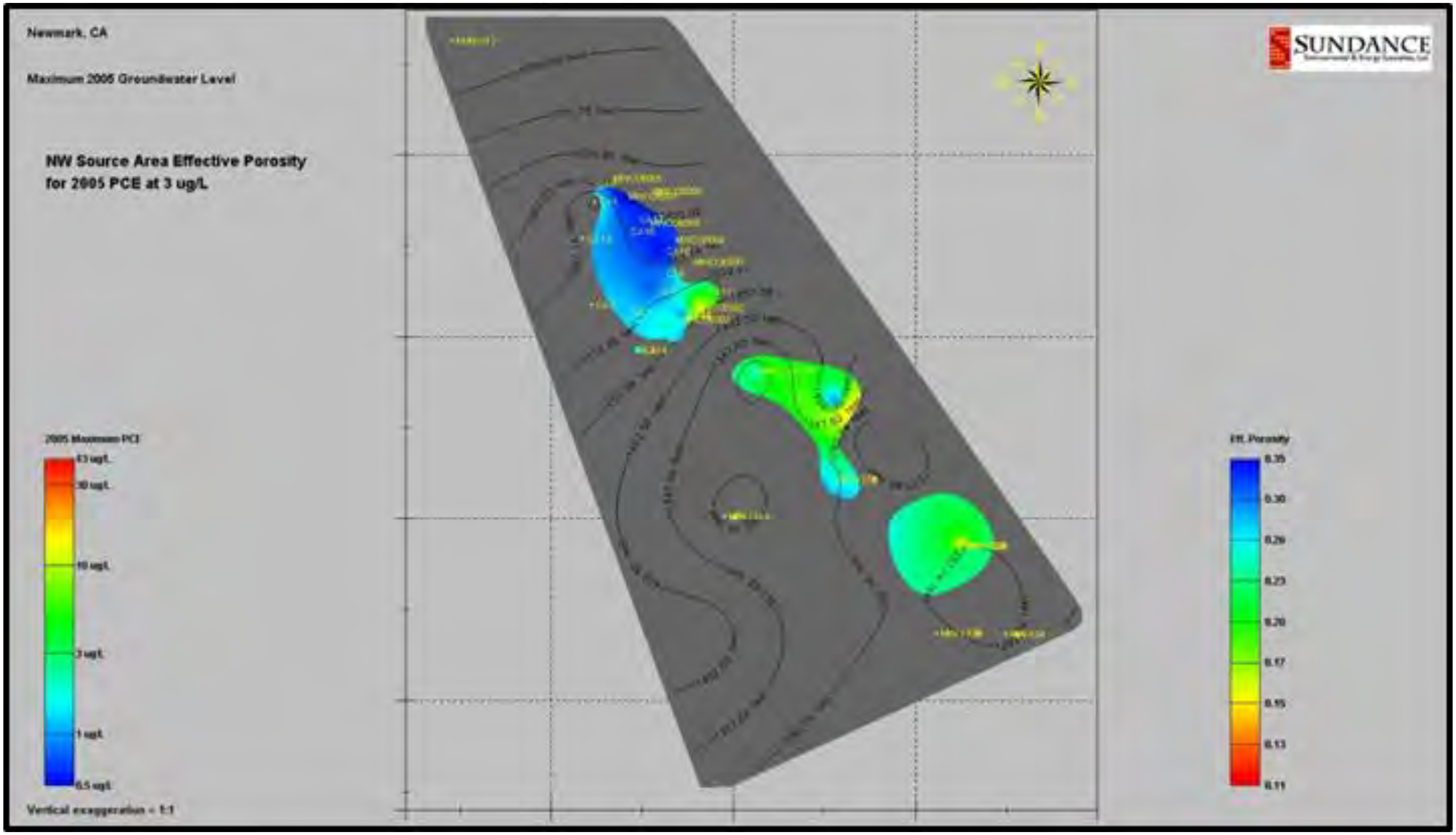


Figure 6.7. Effective porosity weighted concentration (Fig. 6.5 concentration times Fig. 6.6 effective porosity).

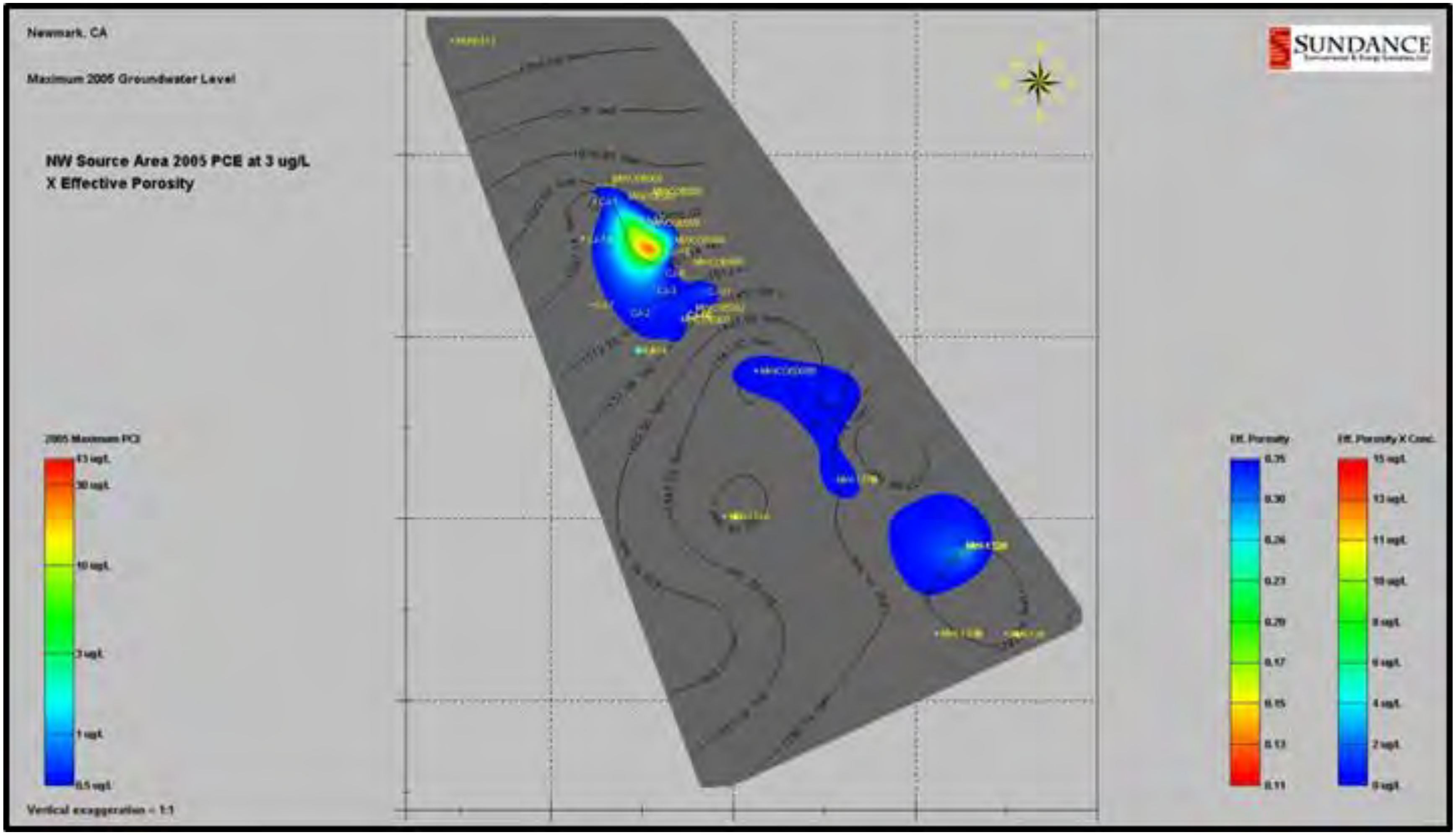


Figure 6.8. Verification of geology results with slices compared to original boring logs.

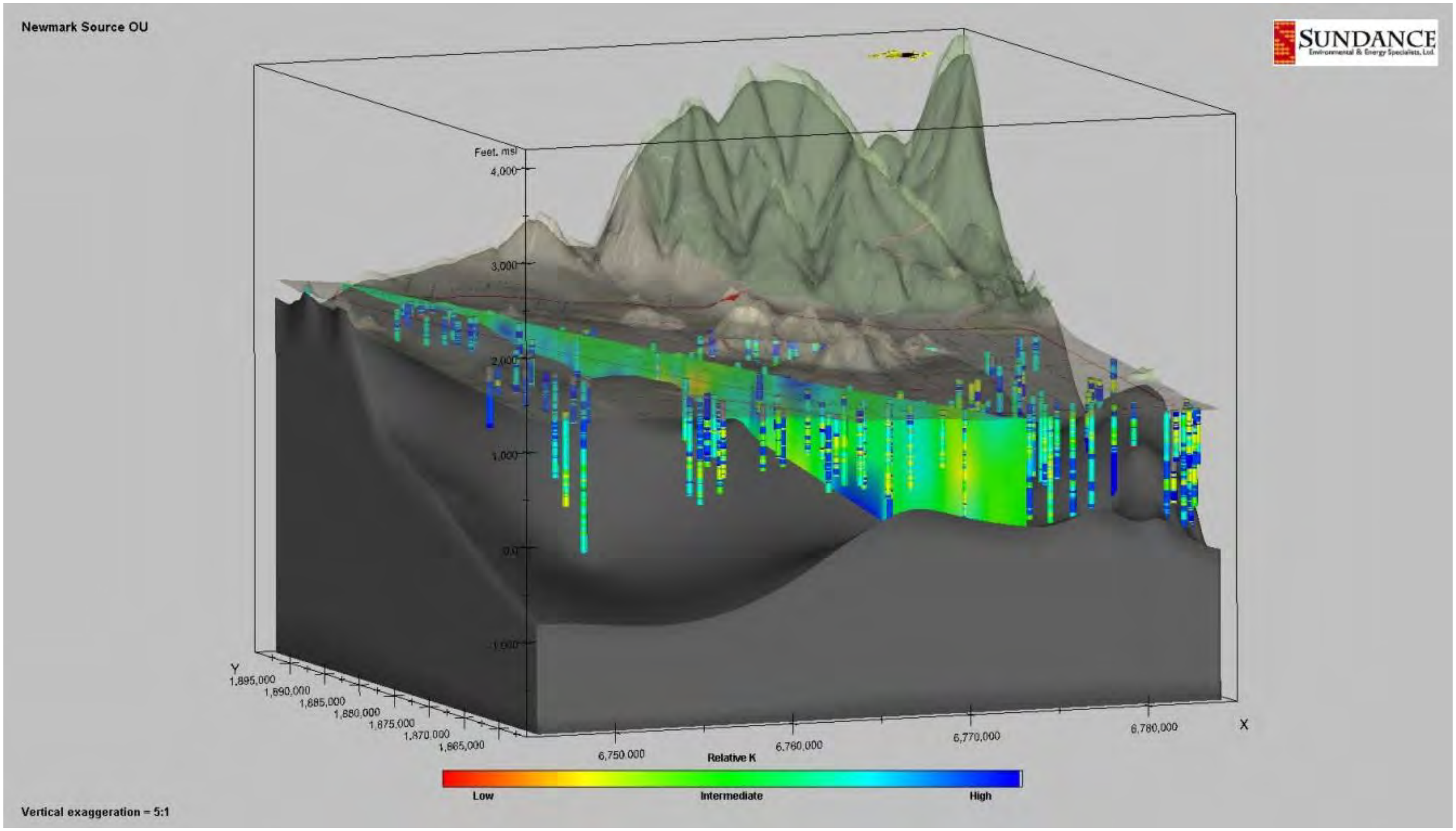


Figure 6.9. Comparison of Stantec (2008) and Sundance geology results. Both horizontal slices are at 1,732 feet elevation.

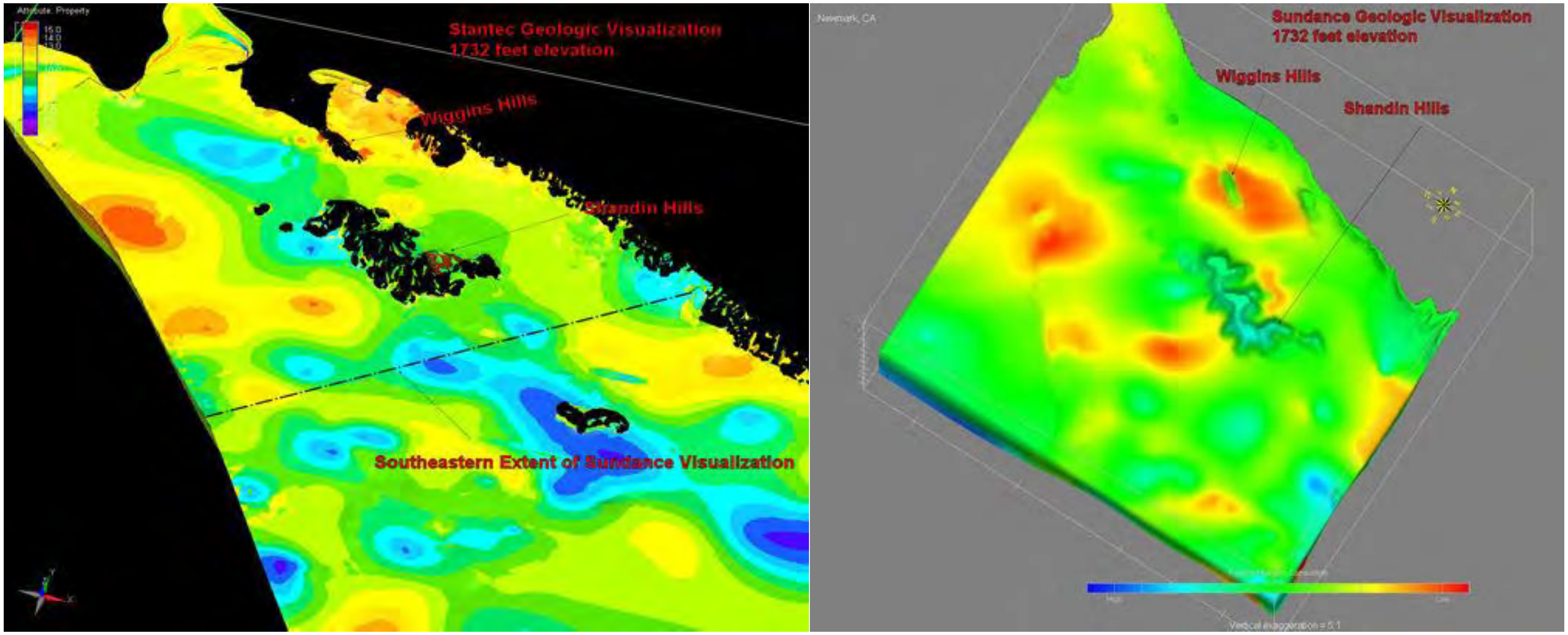


Figure 6.10. Groundwater levels in 1983 (Stantec 2008). Inset box shows groundwater levels in Source OU in 1983.

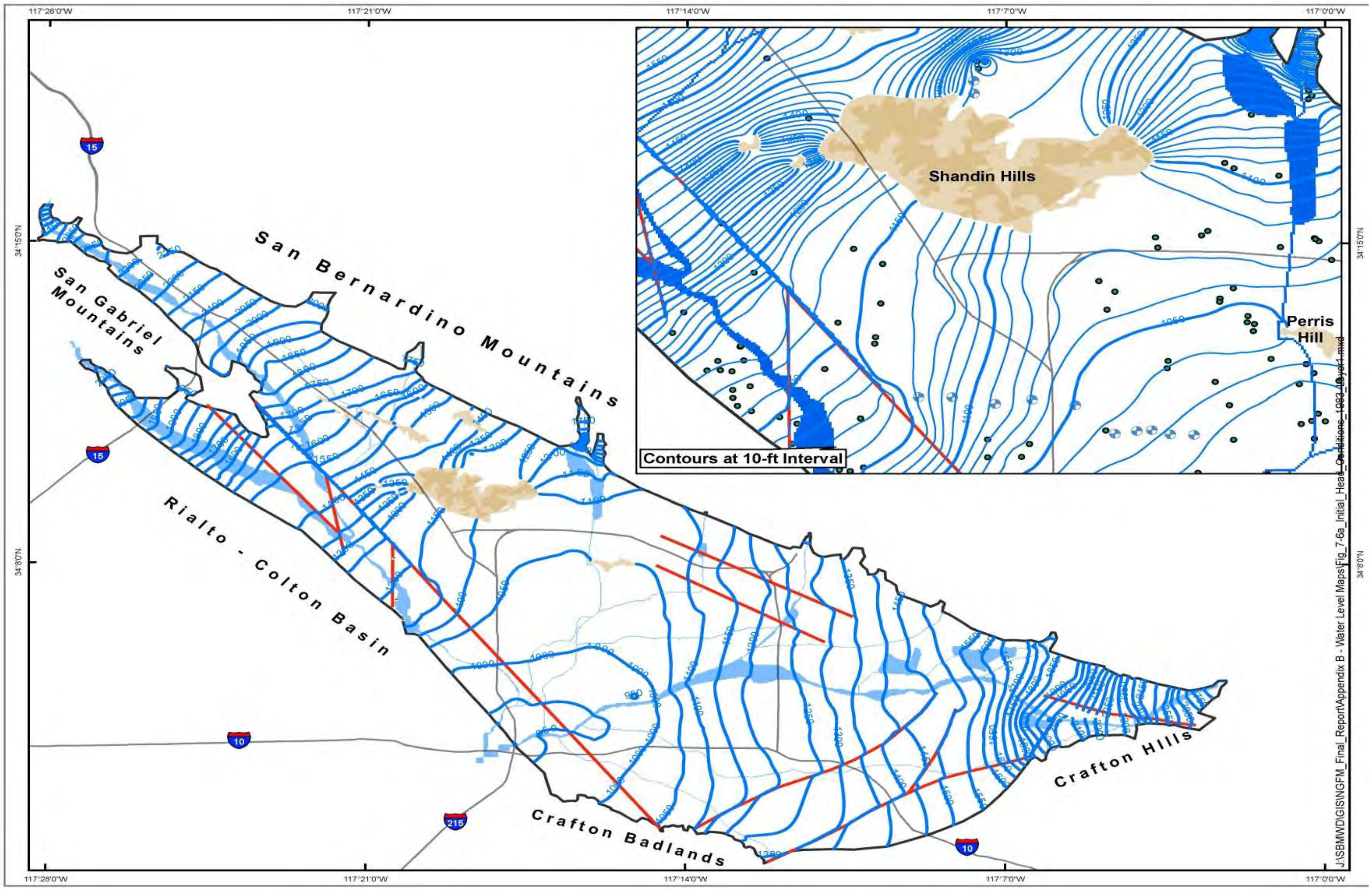


Figure 6.11. Groundwater surface and flow direction from 3DVA for Source OU in 1997.

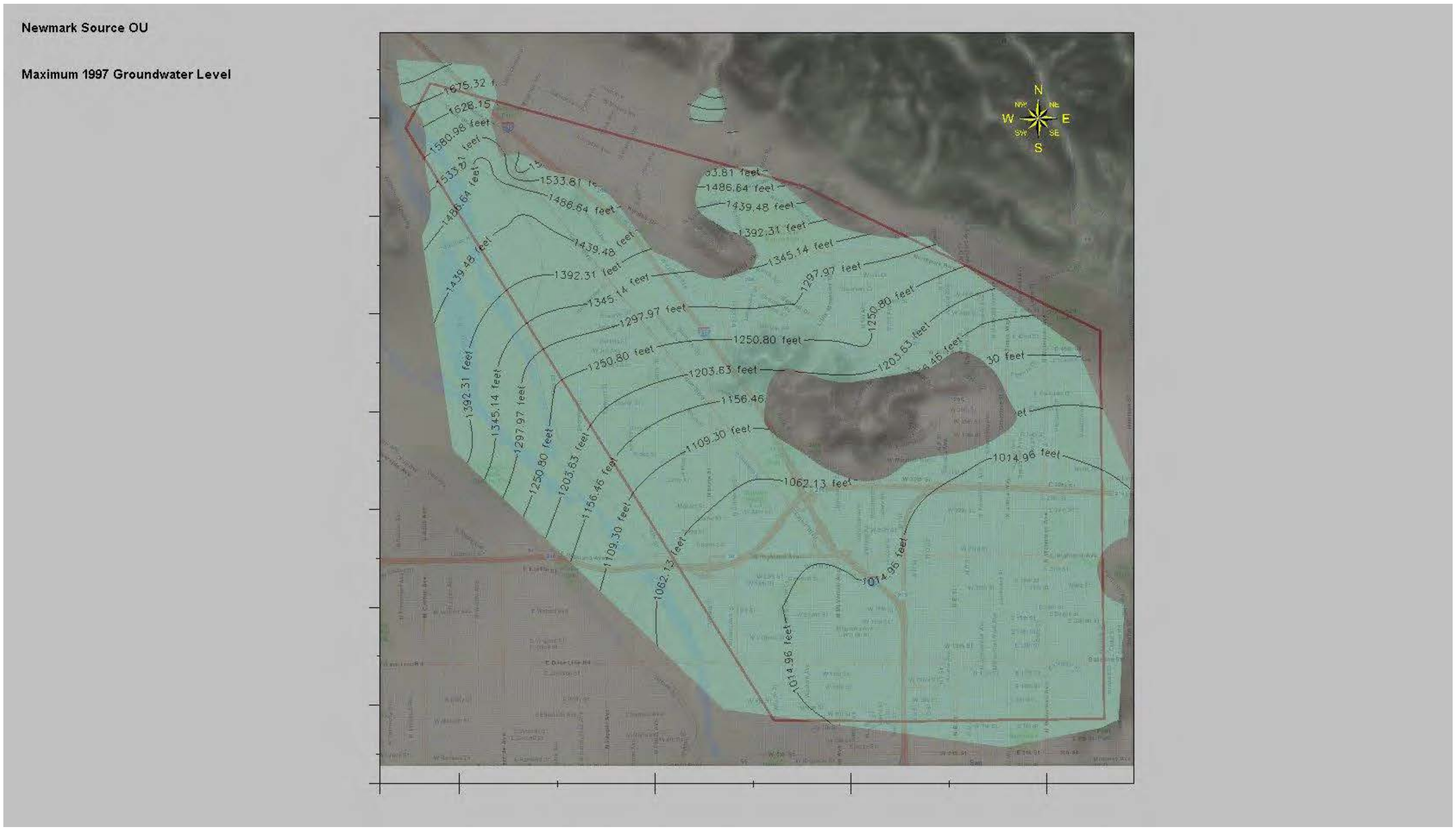


Figure 6.12. PCE plume at 5 µg/L verified against sampling data for each year.

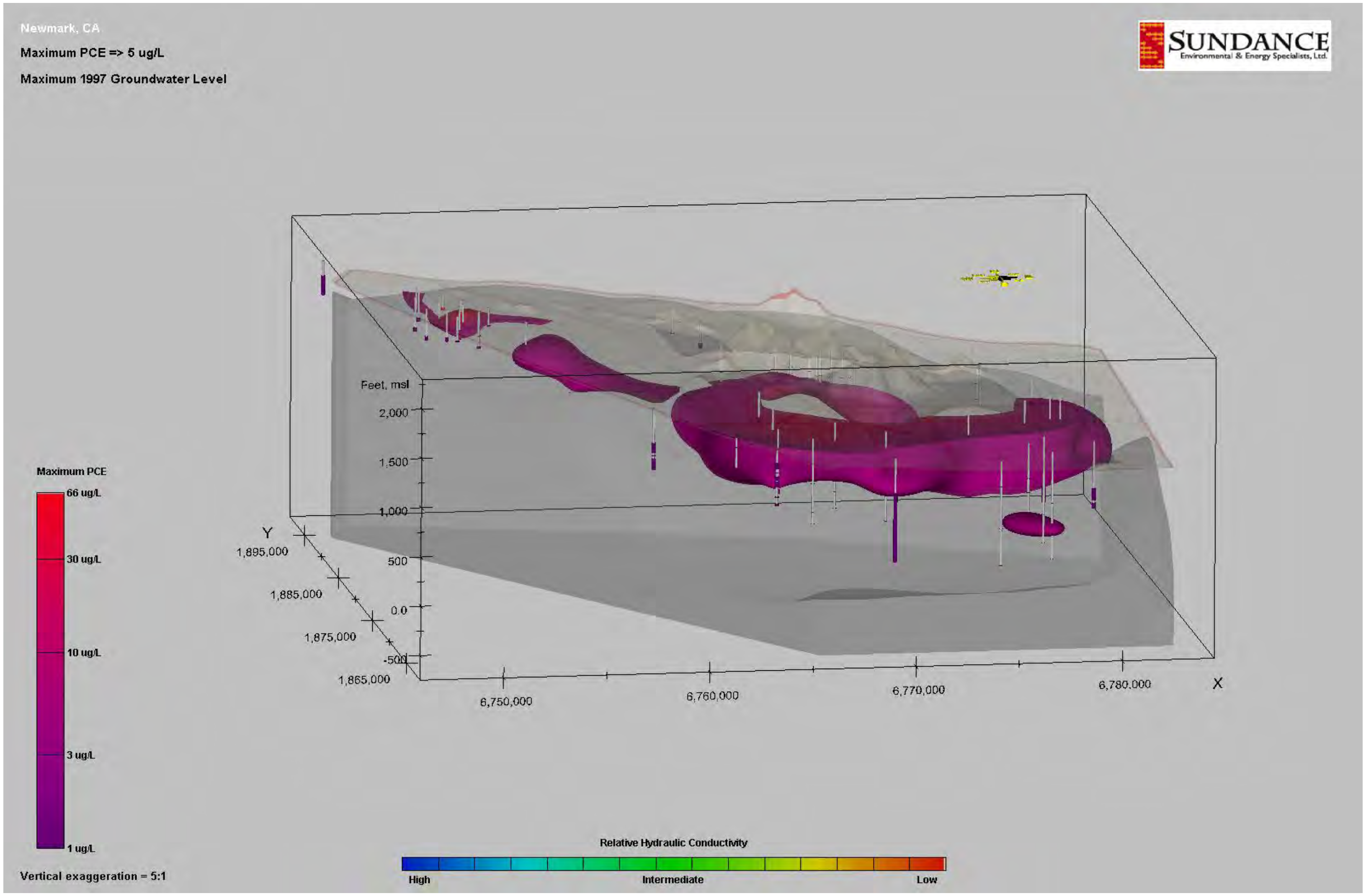


Figure 7.1. 3DVA lithology visualization results depicted as relative hydraulic conductivity (K_R).

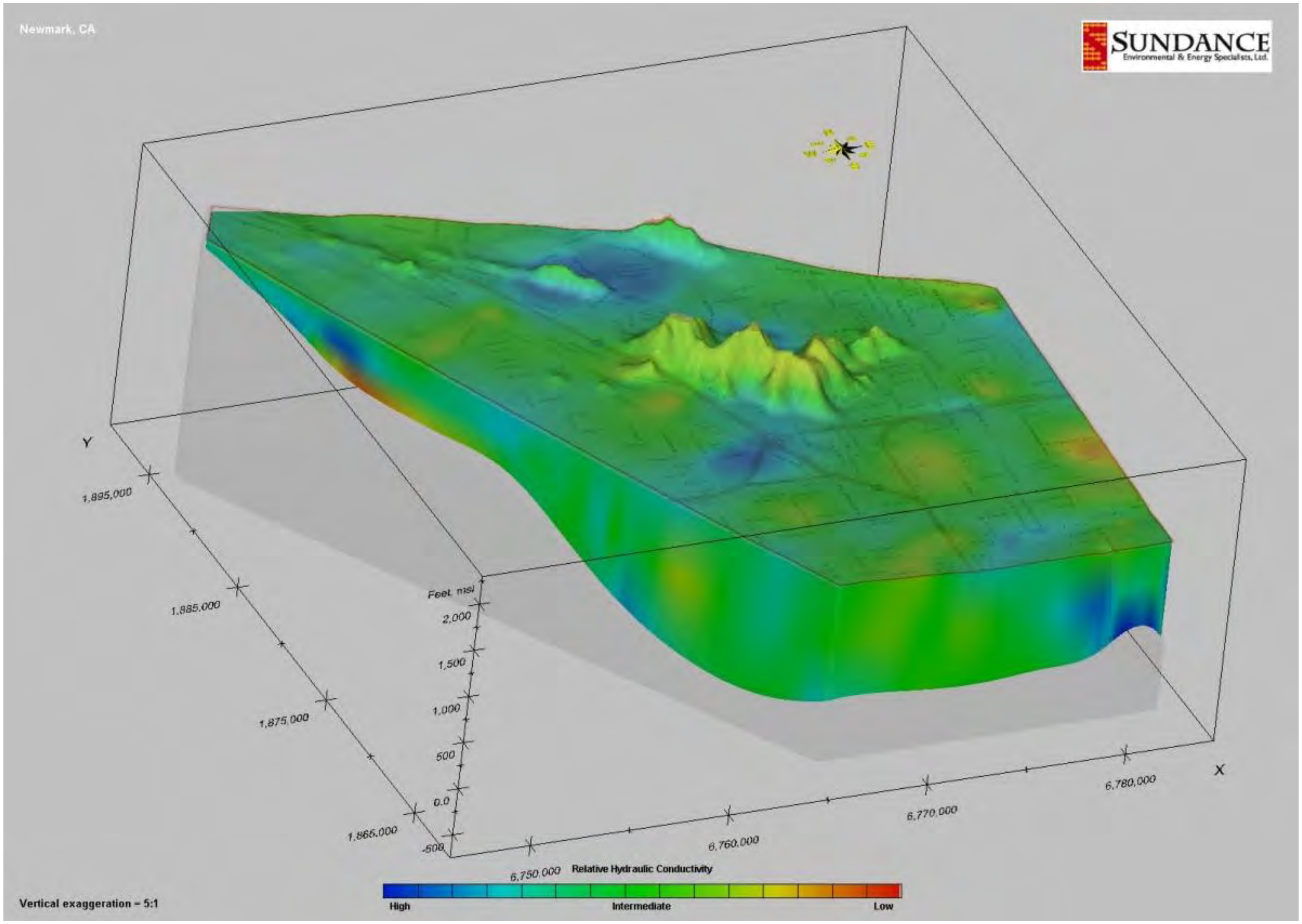


Figure 7.2. Distribution of lowest K_R unconsolidated deposits throughout Source OU.

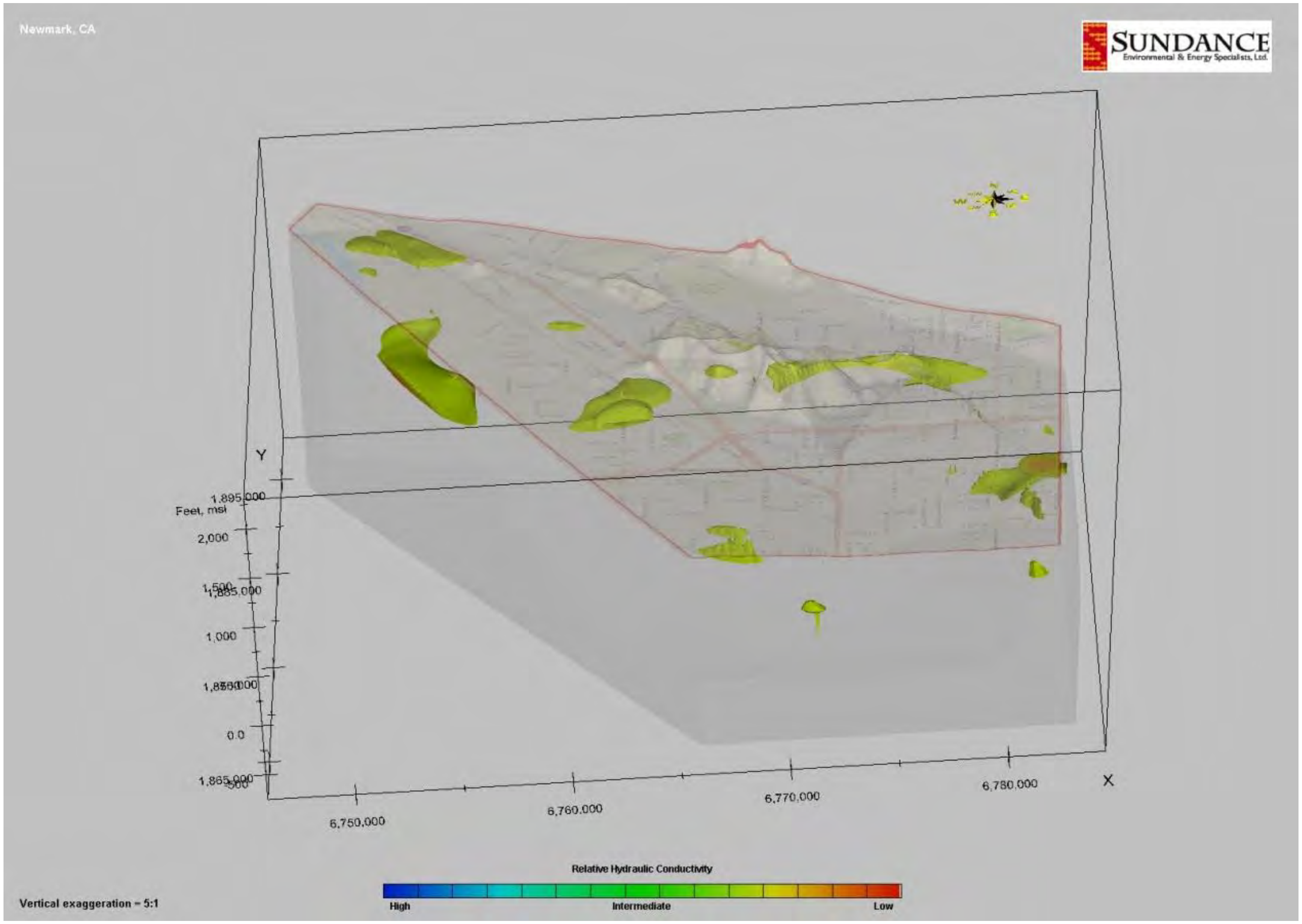


Figure 7.3. Distribution of low to intermediate K_R unconsolidated deposits throughout Source OU.

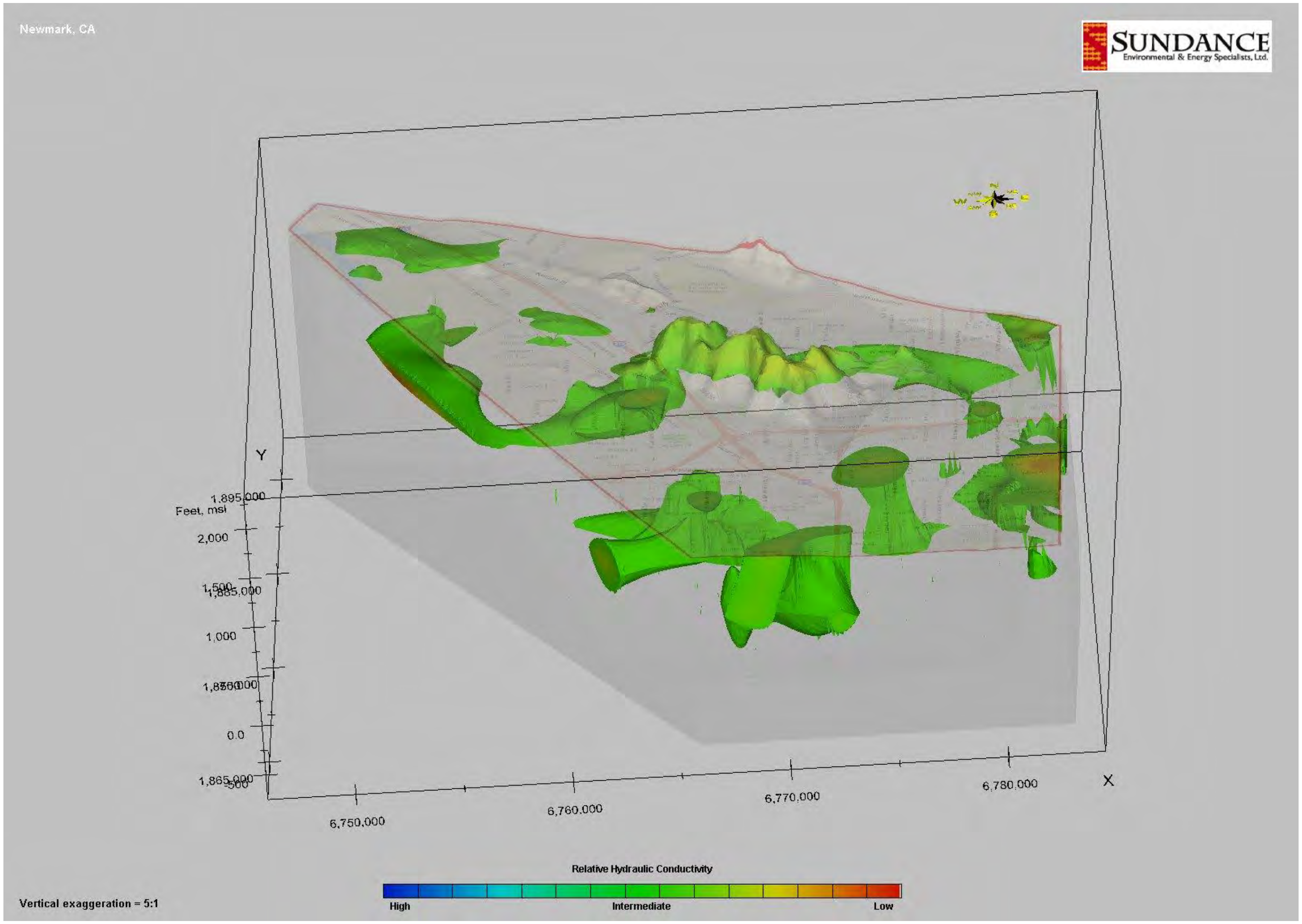


Figure 7.4. Distribution of highest K_R unconsolidated deposits throughout Source OU.

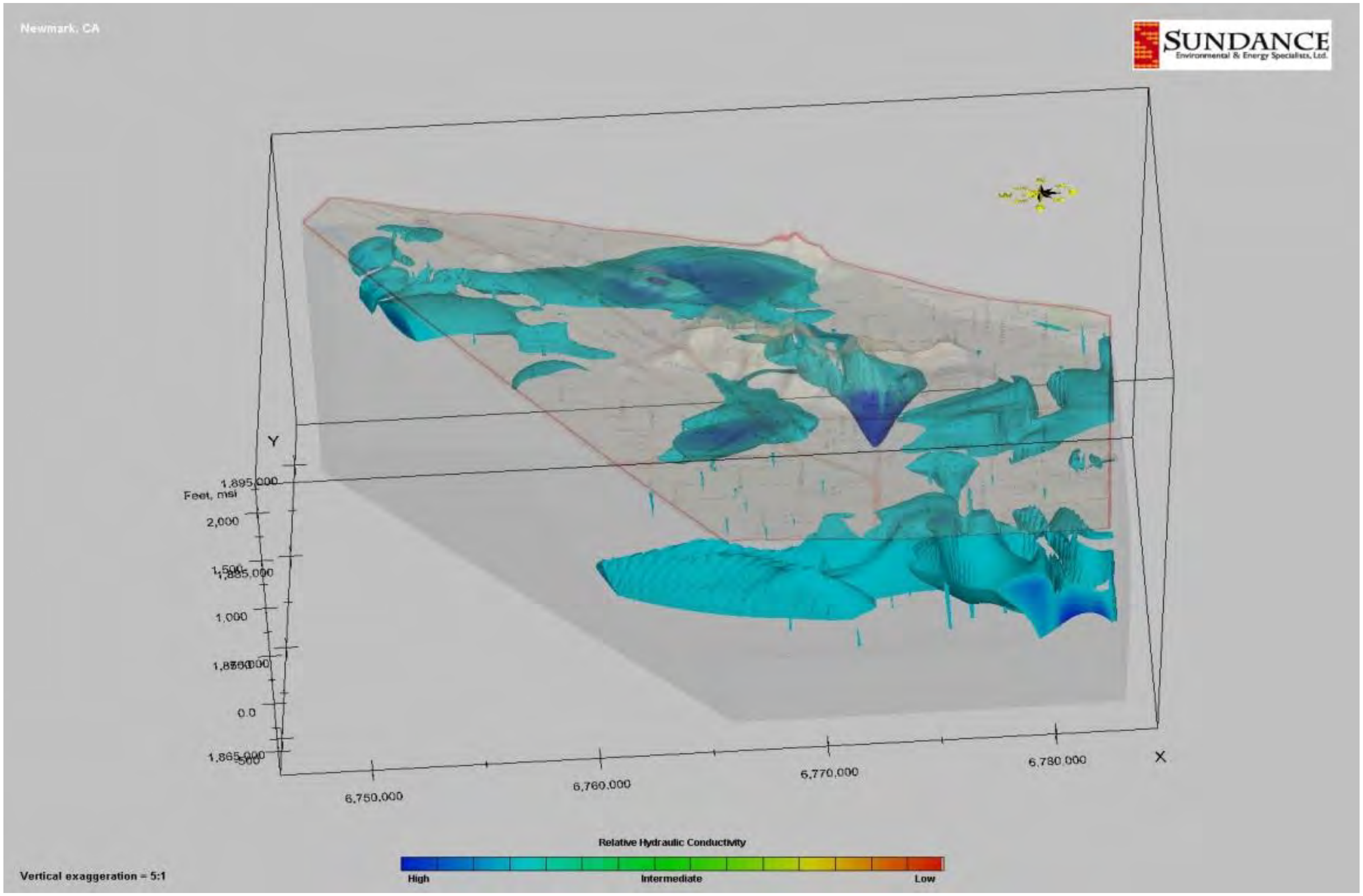


Figure 7.5. Example of vertical lithology slice from 3DVA geology visualization.

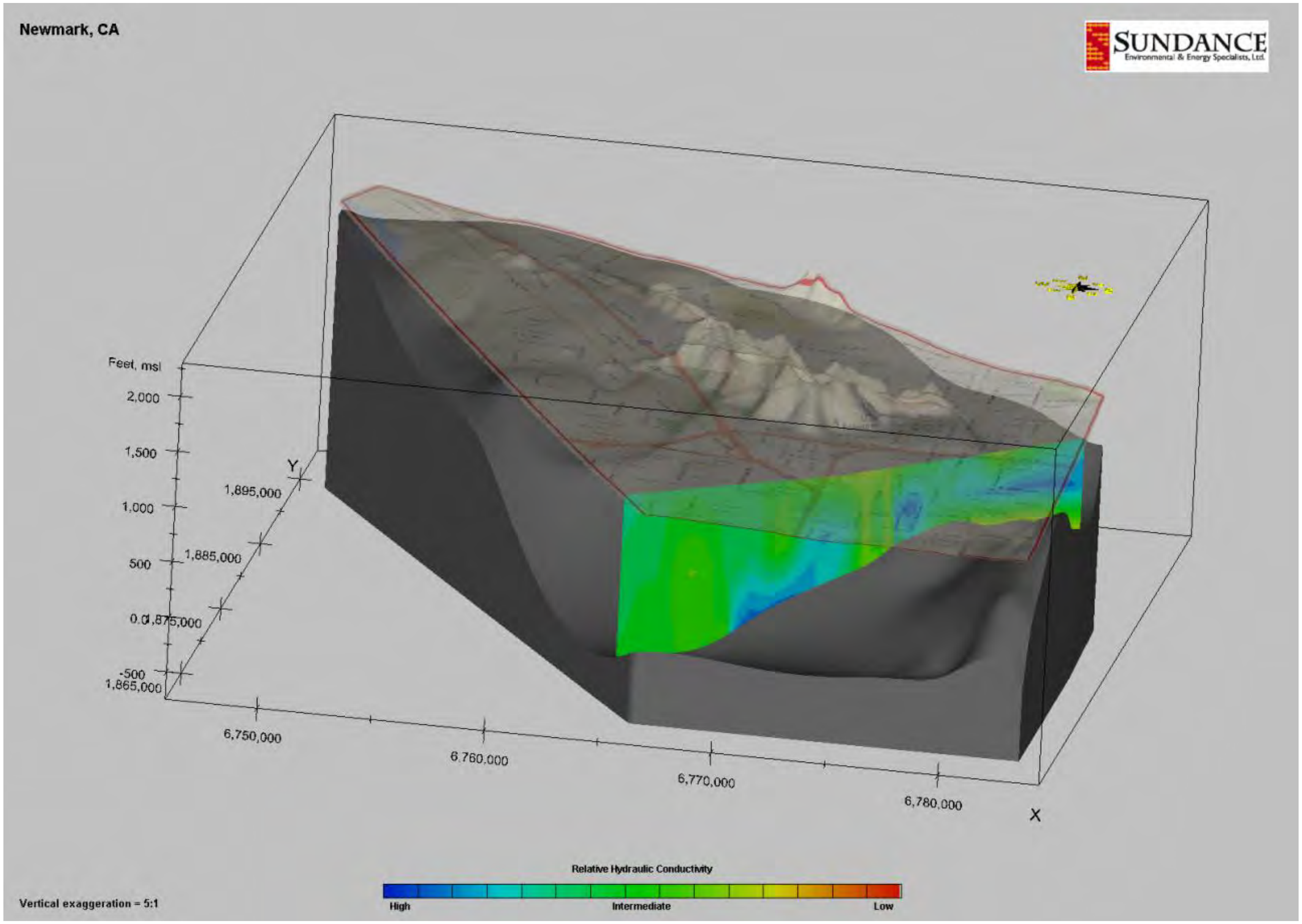


Figure 7.6. Side view of 4DIM file for orientation in viewing potentiometric fluctuations in the Source OU from 1997-2012.

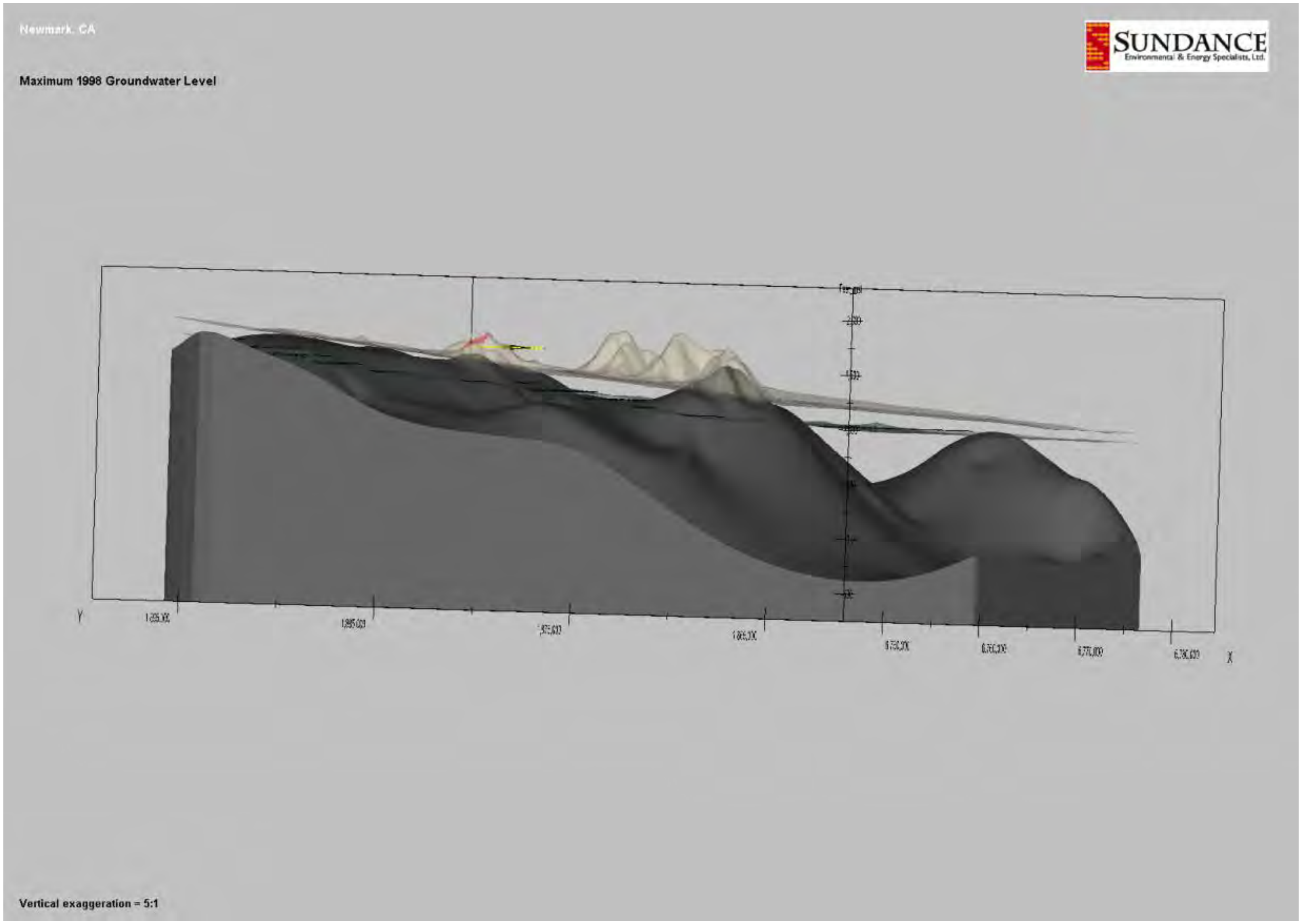


Figure 7.7. Source OU-wide distribution of TCE concentrations in 2005.

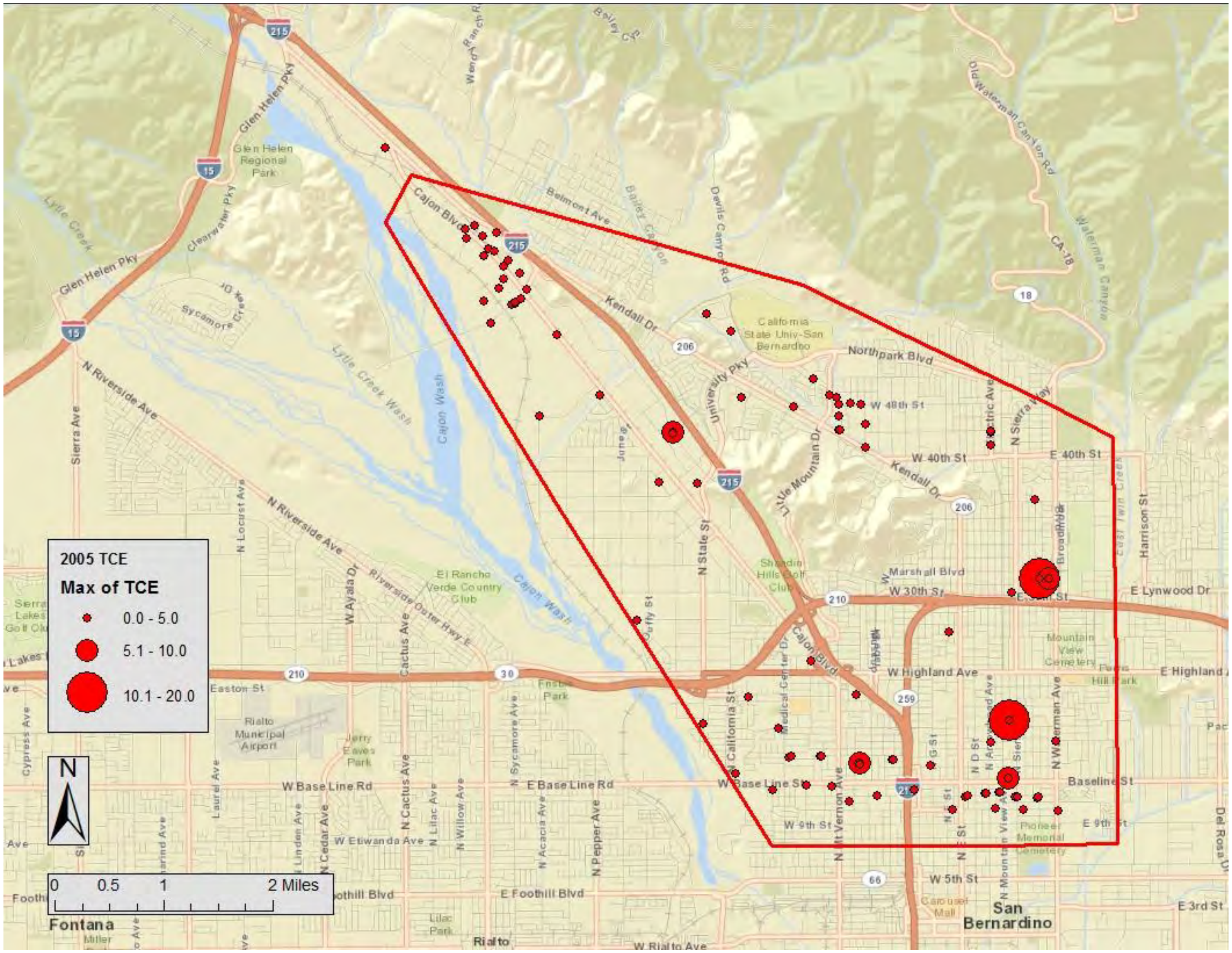
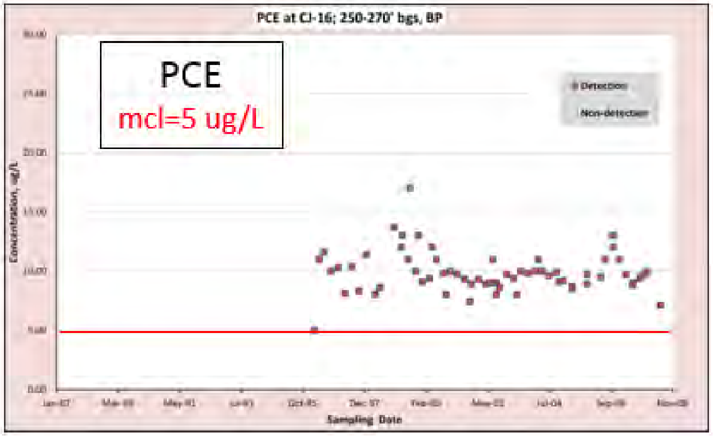
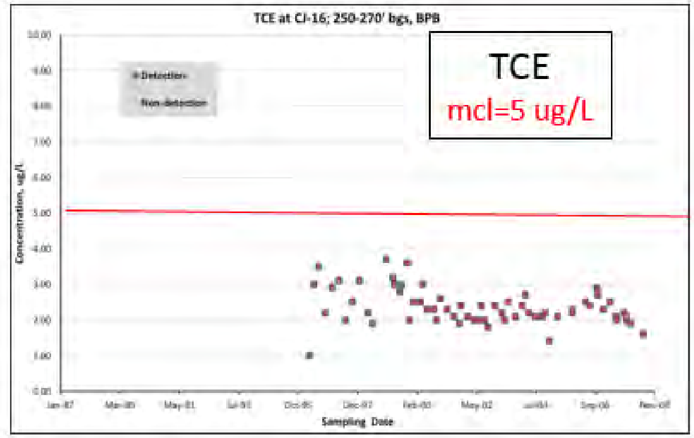


Figure 7.8. Trend analysis for PCE, TCE, and cis-1,2-DCE in monitoring well CJ-16 from 1995 through 2008.





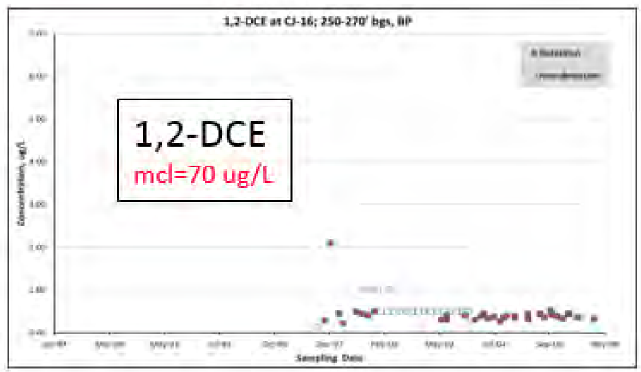


Figure 7.9. Source OU-wide distribution of cis-1,2-DCE concentrations in 2005.

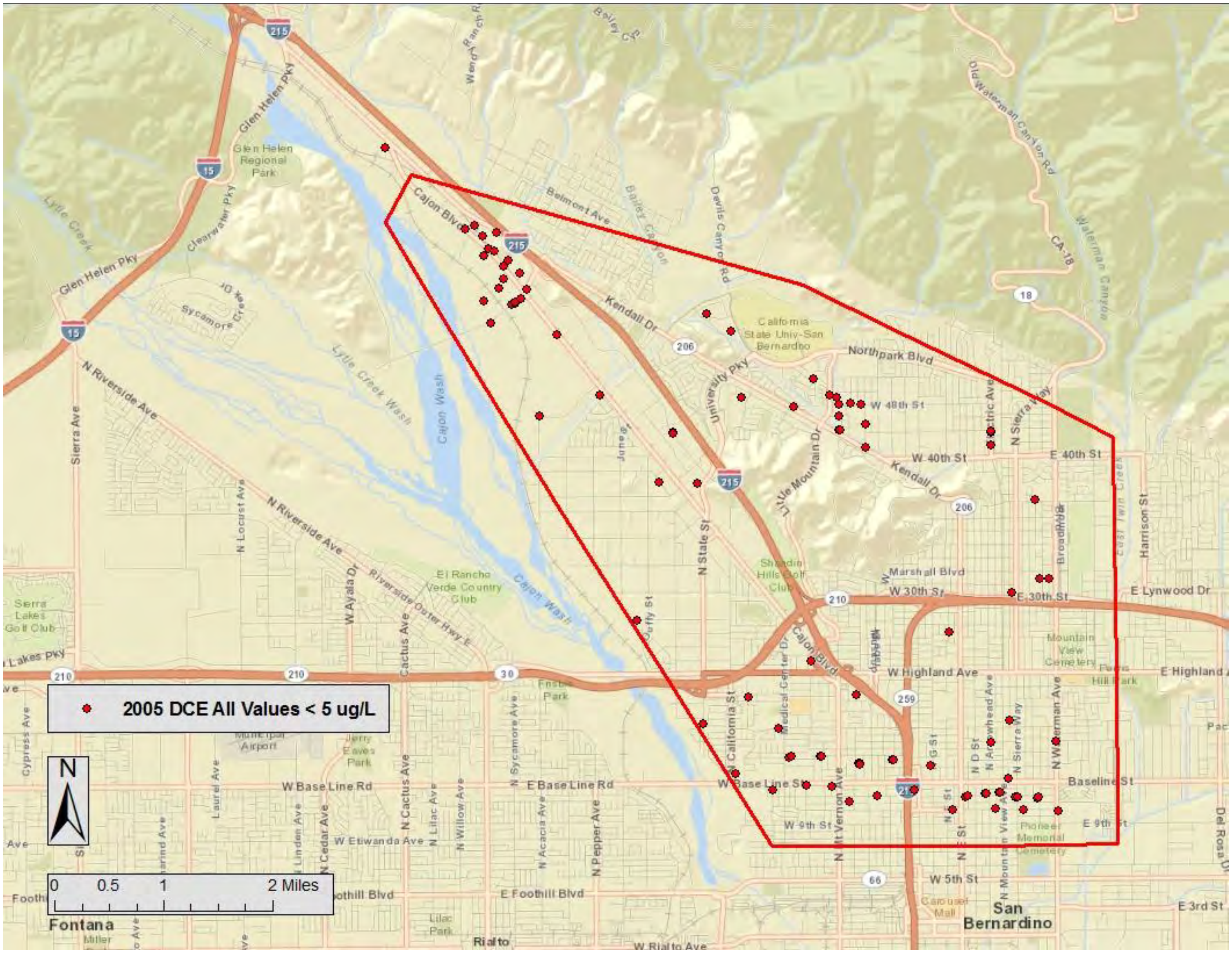


Figure 7.10. Extent of PCE plume in 1997 visualized at 20 μg/L.

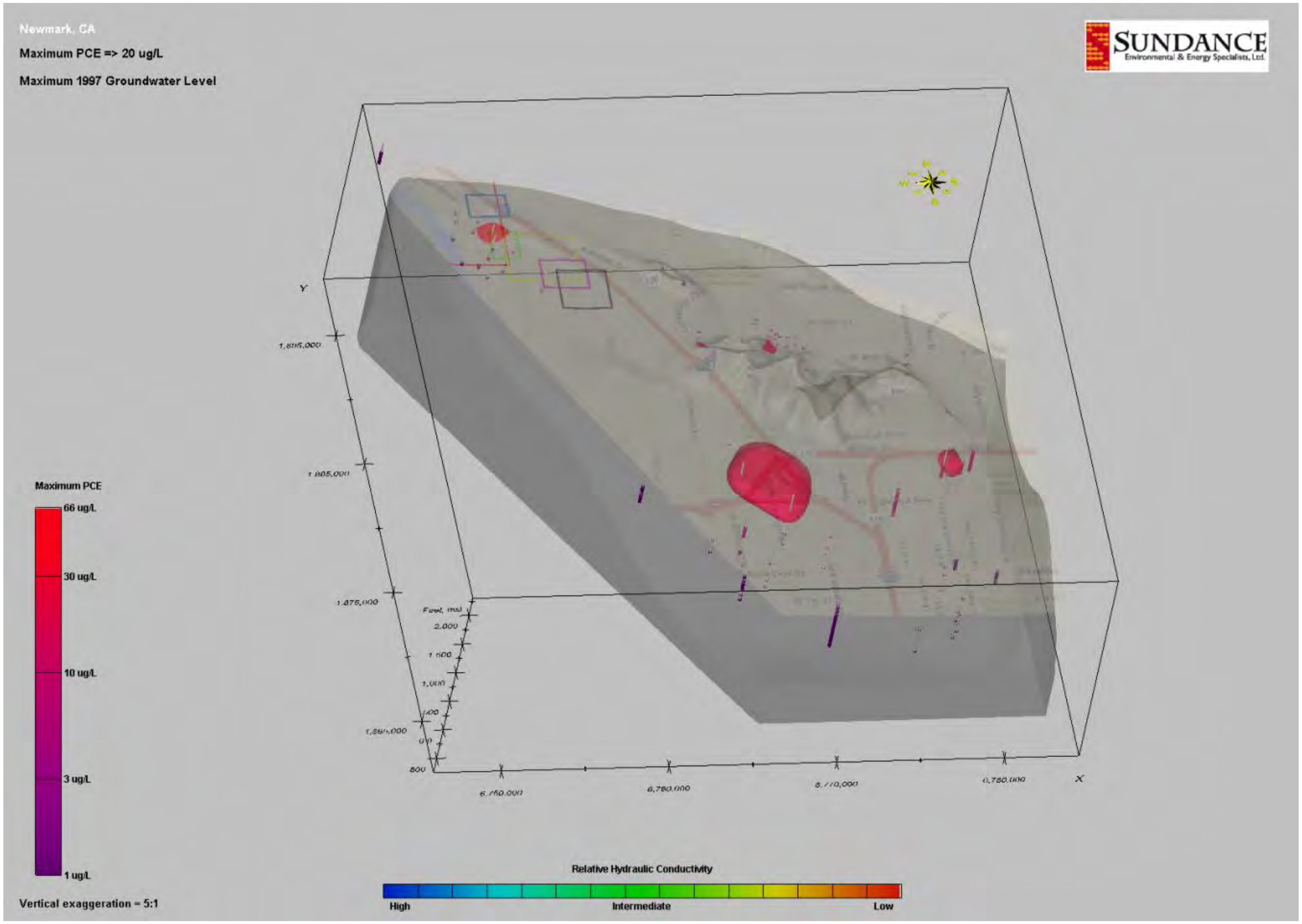


Figure 7.11. Extent of PCE plume in 1997 visualized at 10 µg/L.

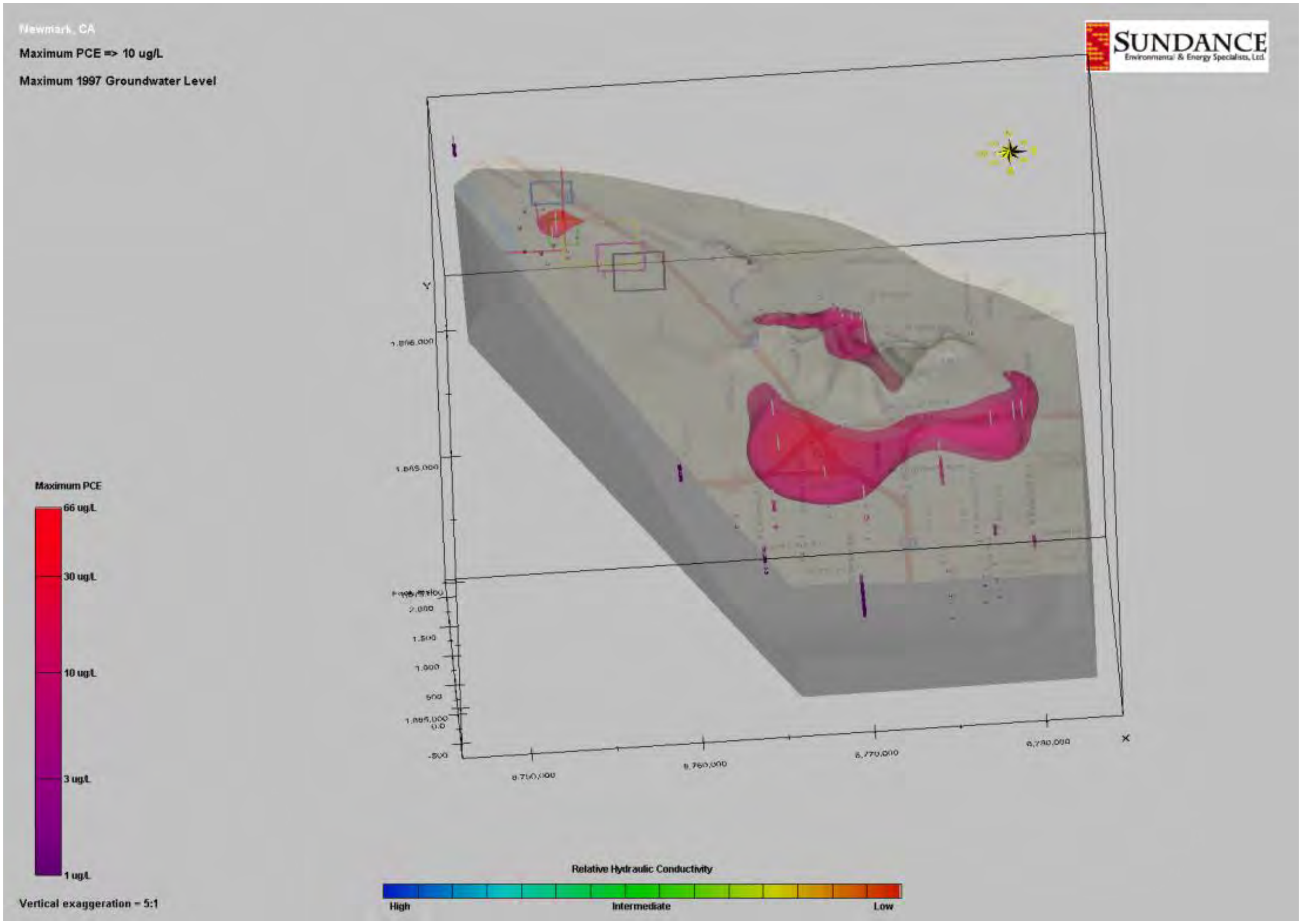


Figure 7.12. Extent of PCE plume in 1997 visualized at 5 µg/L.

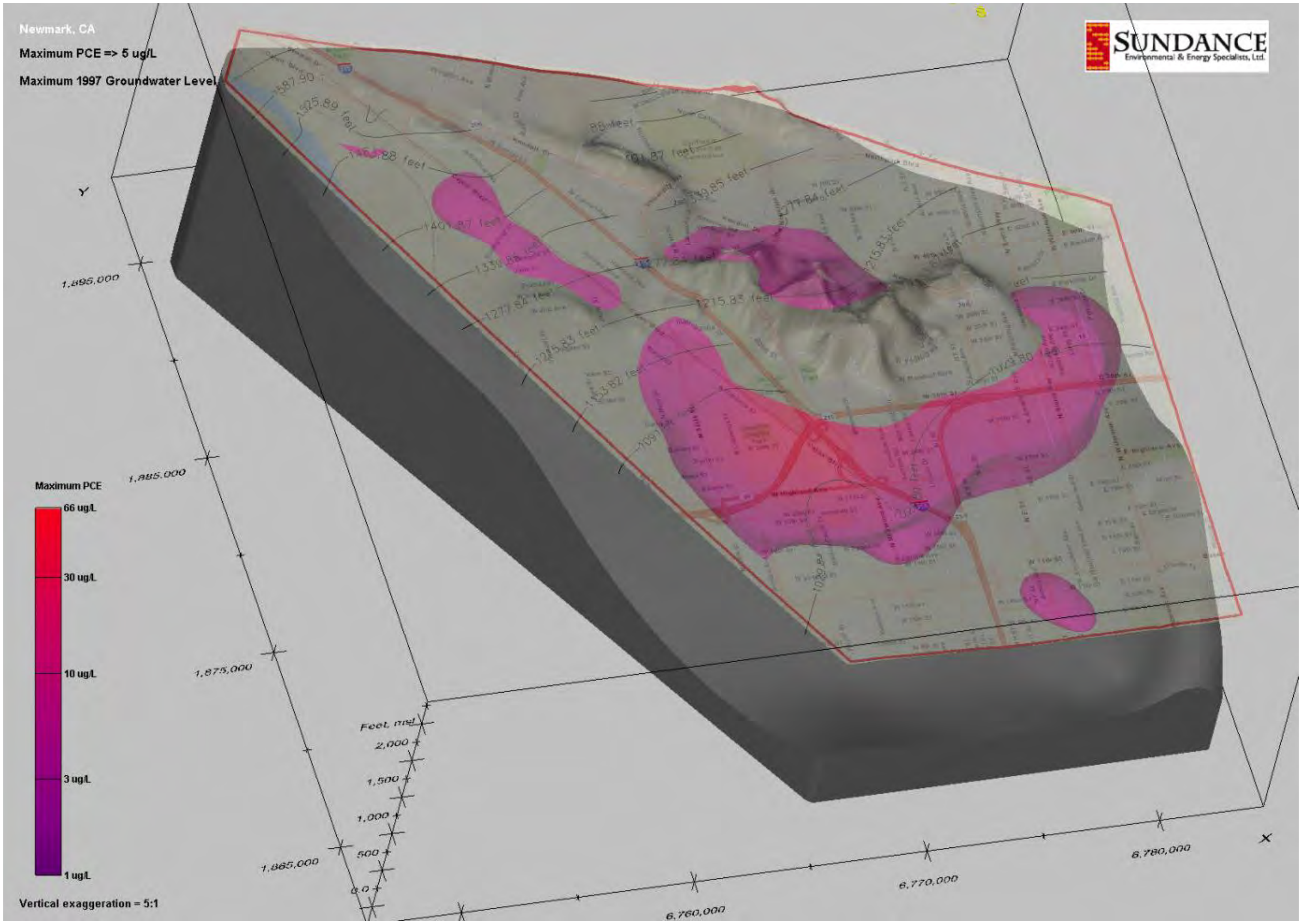


Figure 7.13. Extent of PCE plume in 2008 visualized at 5 µg/L showing decreased distribution compared to 1997, as shown in Figure 7.12.

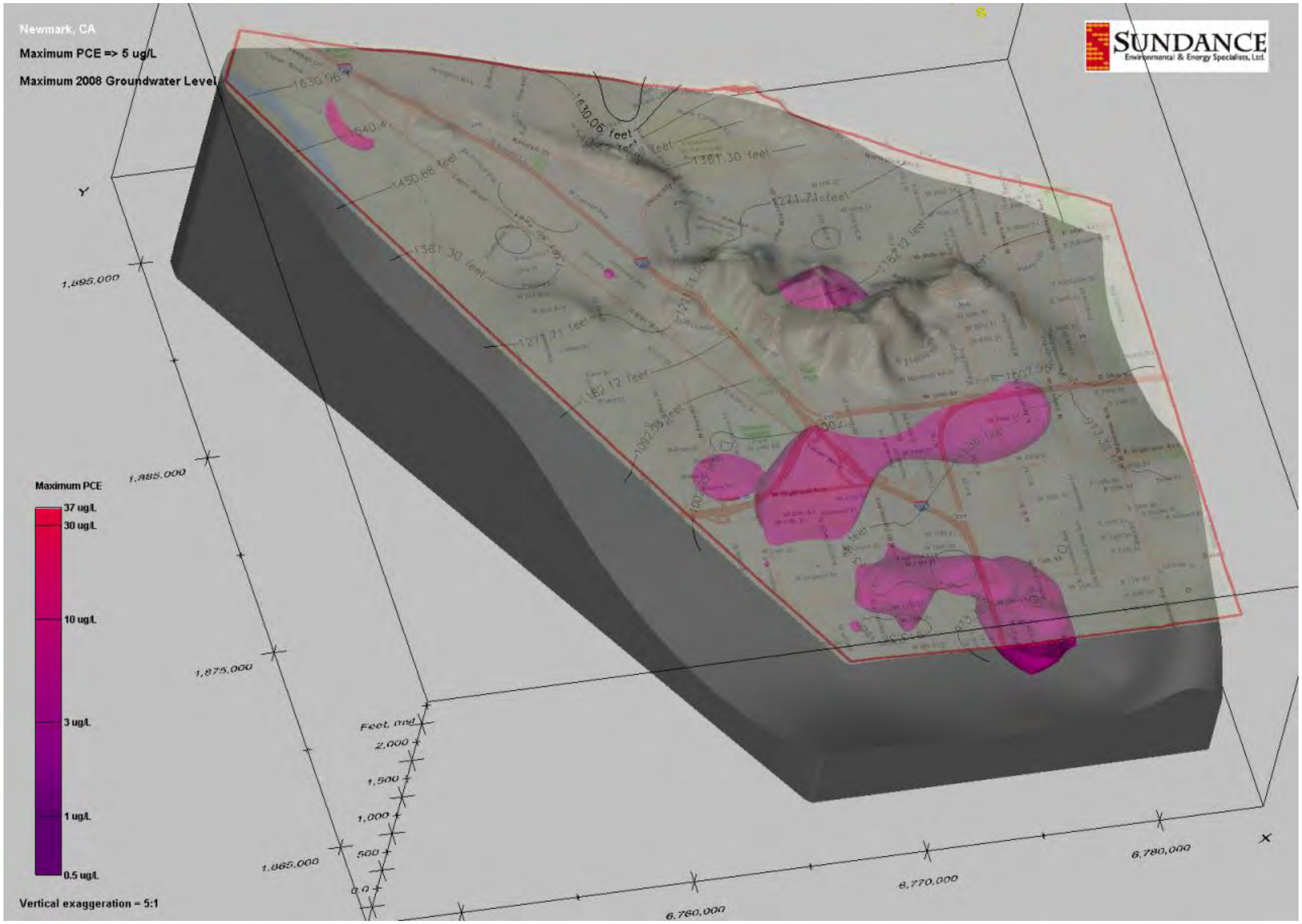


Figure 7.14. Highest PCE concentrations in groundwater located at CJ-10 from 1997-2012.

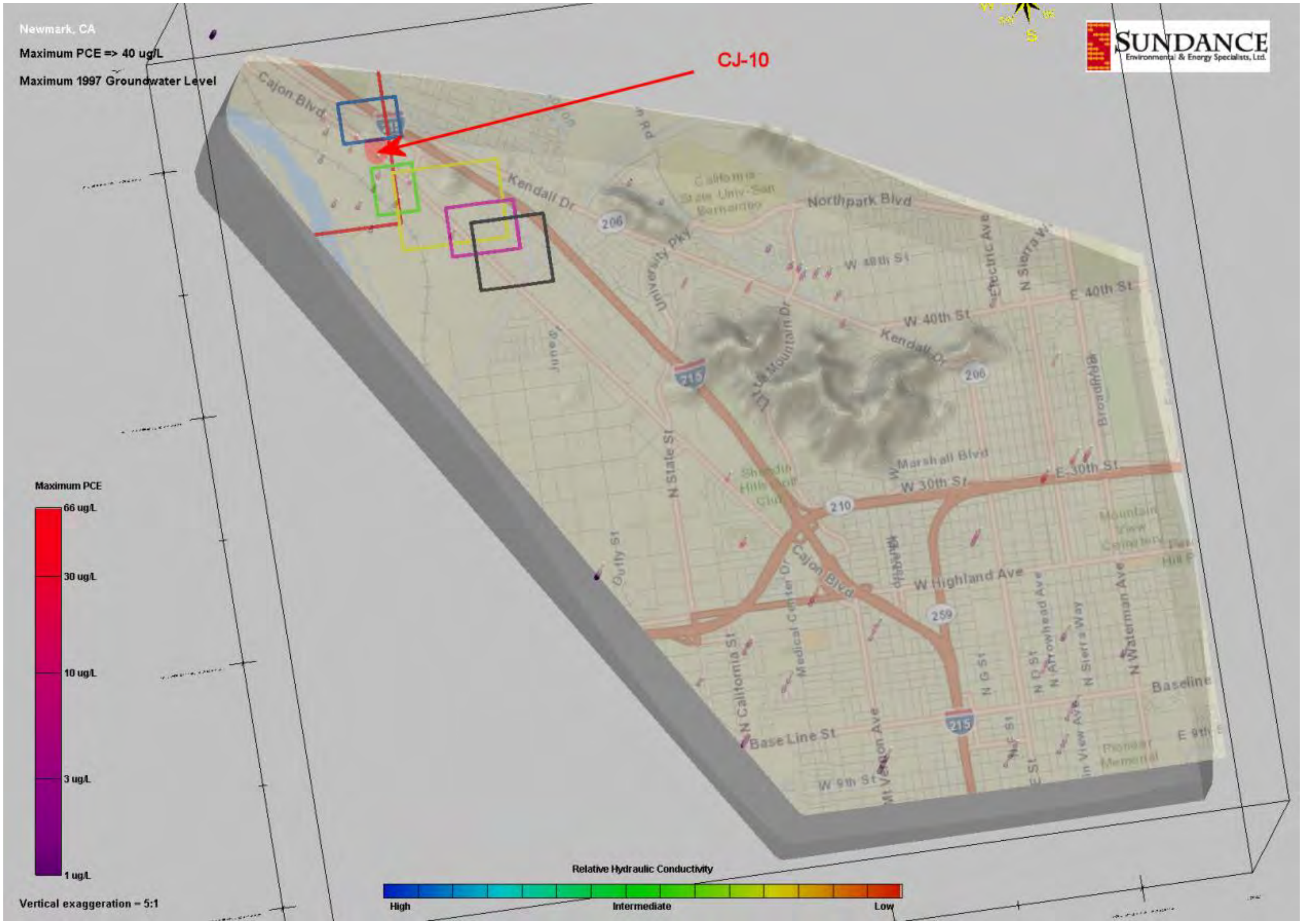


Figure 8.1. Bifurcation of plume to form Newmark and Muscoy plumes at location northwest of Shandin Hills.

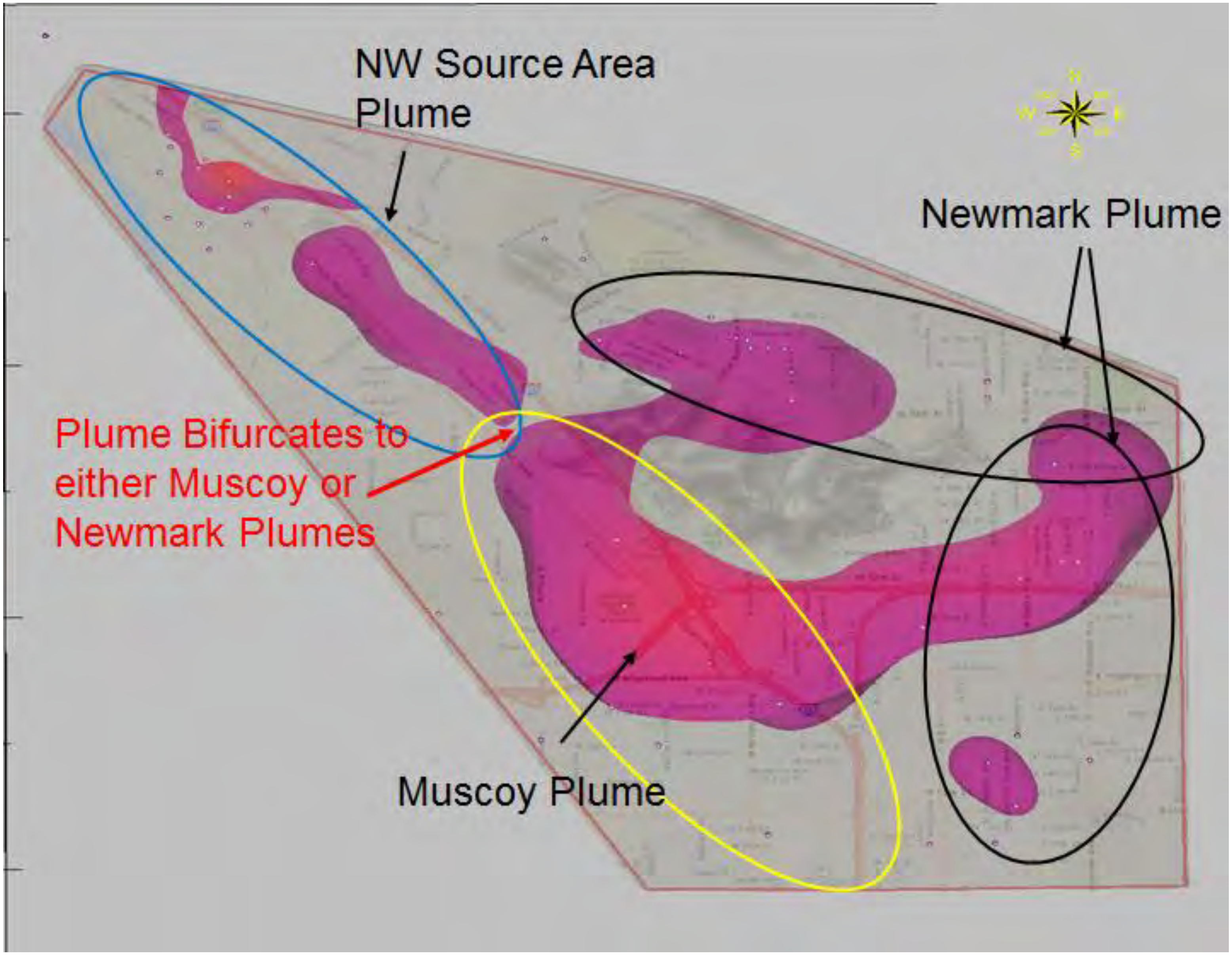


Figure 8.2. Integrated visualization results illustrate confluence of site features controlling migration of the Northwest Source Area Plume to form both the Muscoy and Newmark Plumes.

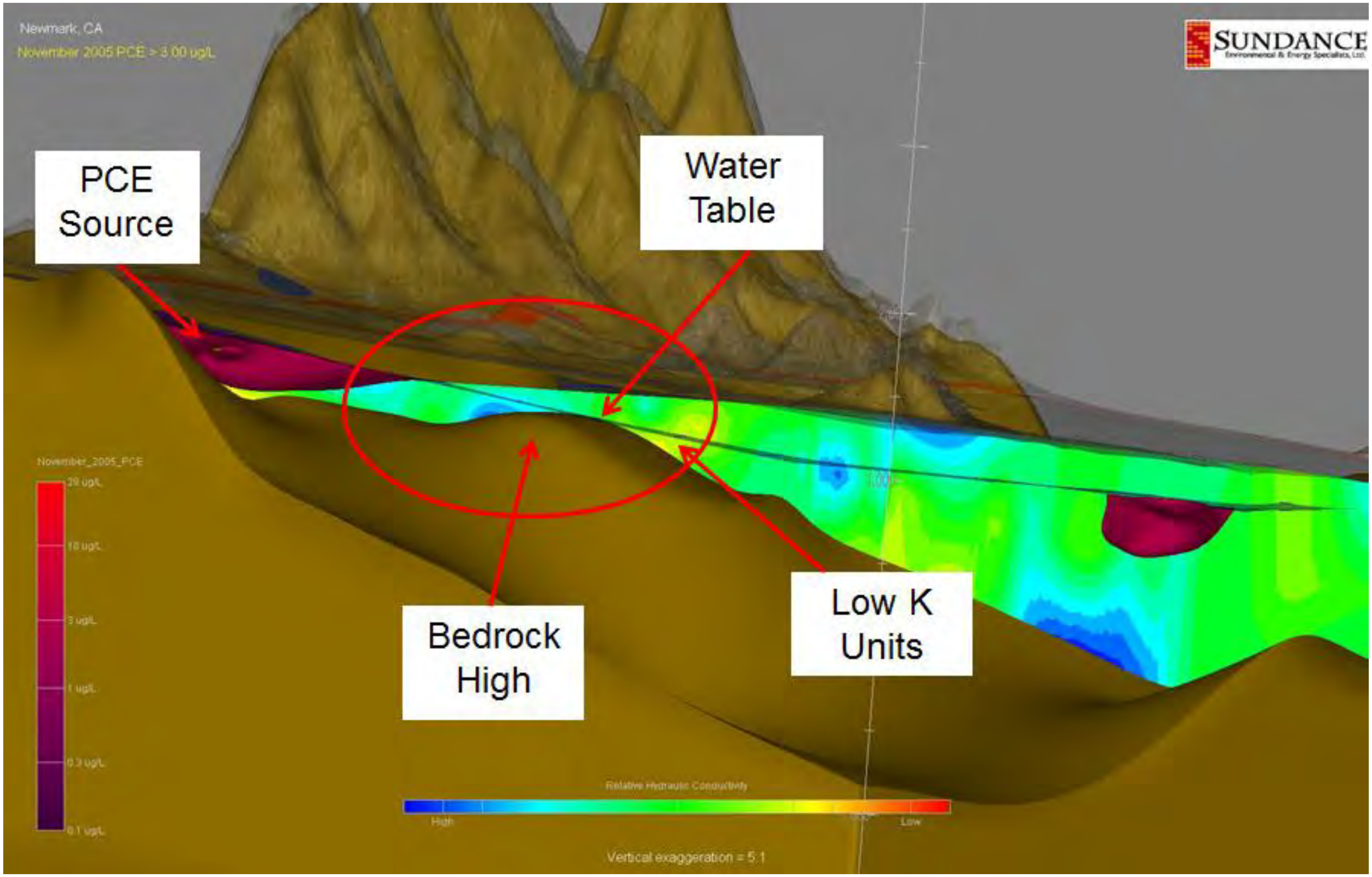


Figure 8.3. Presence of low K_R unconsolidated deposits located northwest of Shandin Hills.

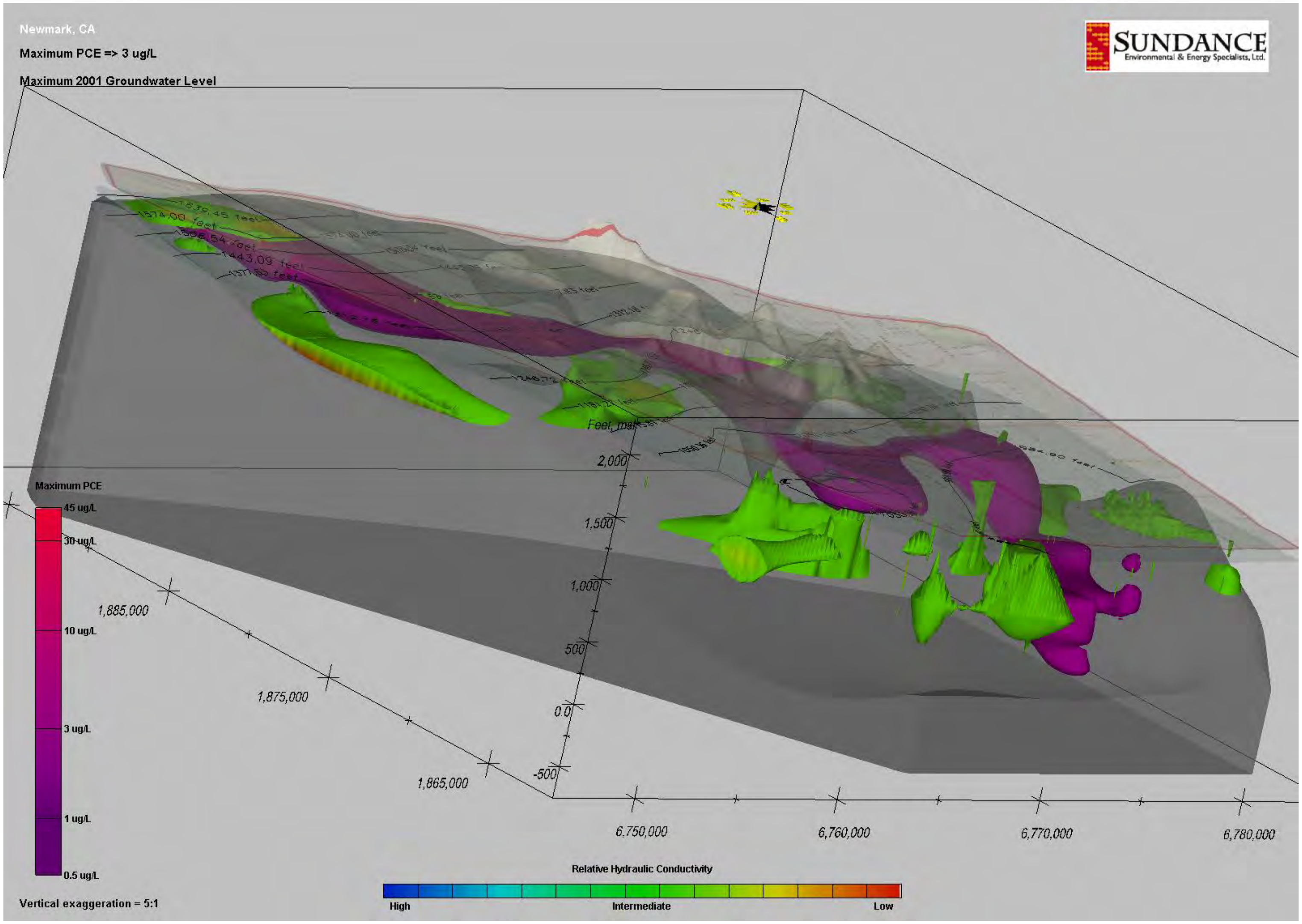


Figure 8.4. High water table elevations allow Northwest Source Area plume to migrate southeast to form Muscoy Plume.

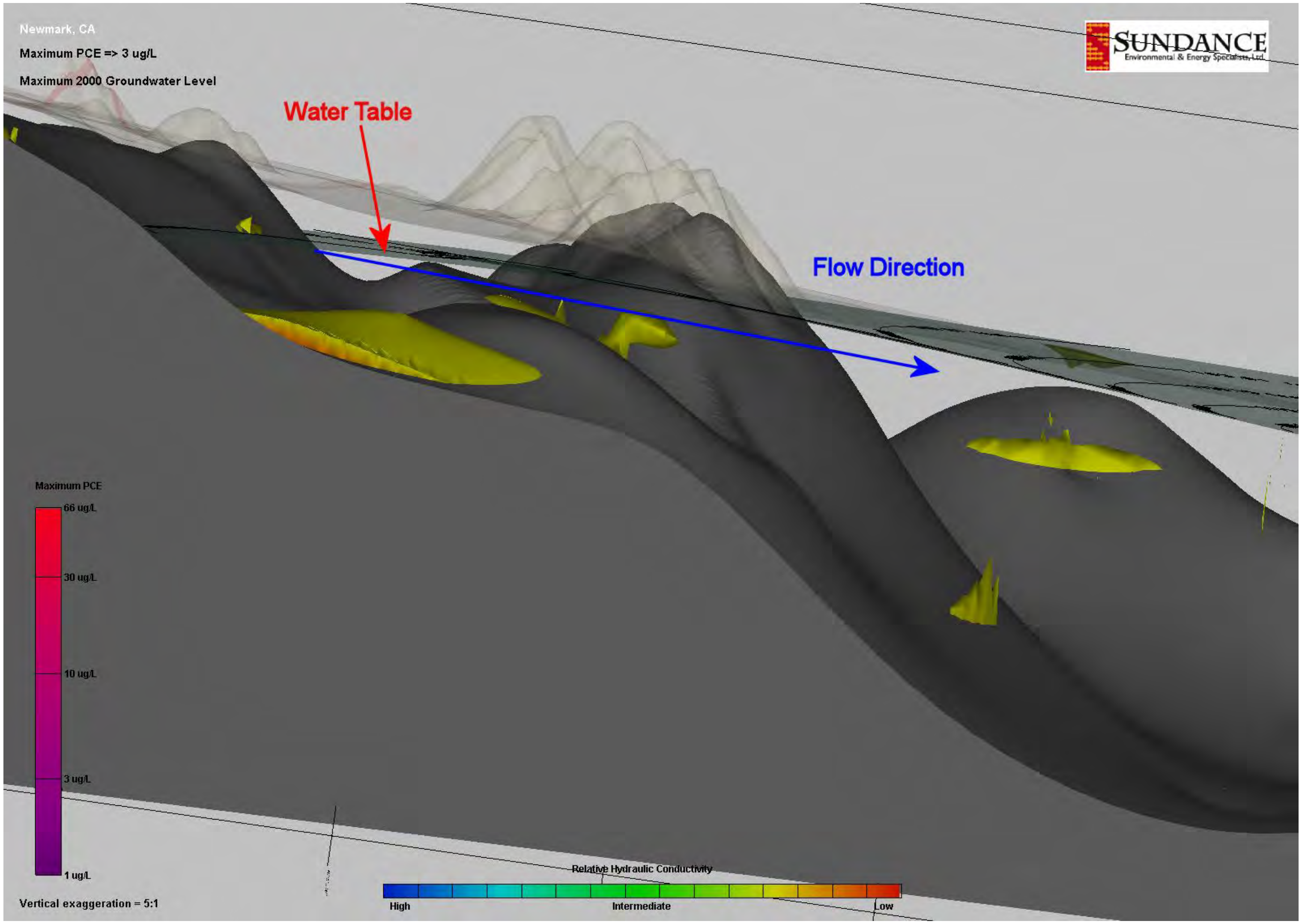


Figure 8.5. Low water table elevations divert the Northwest Source Area Plume to the northeast, forming the Newmark Plume.

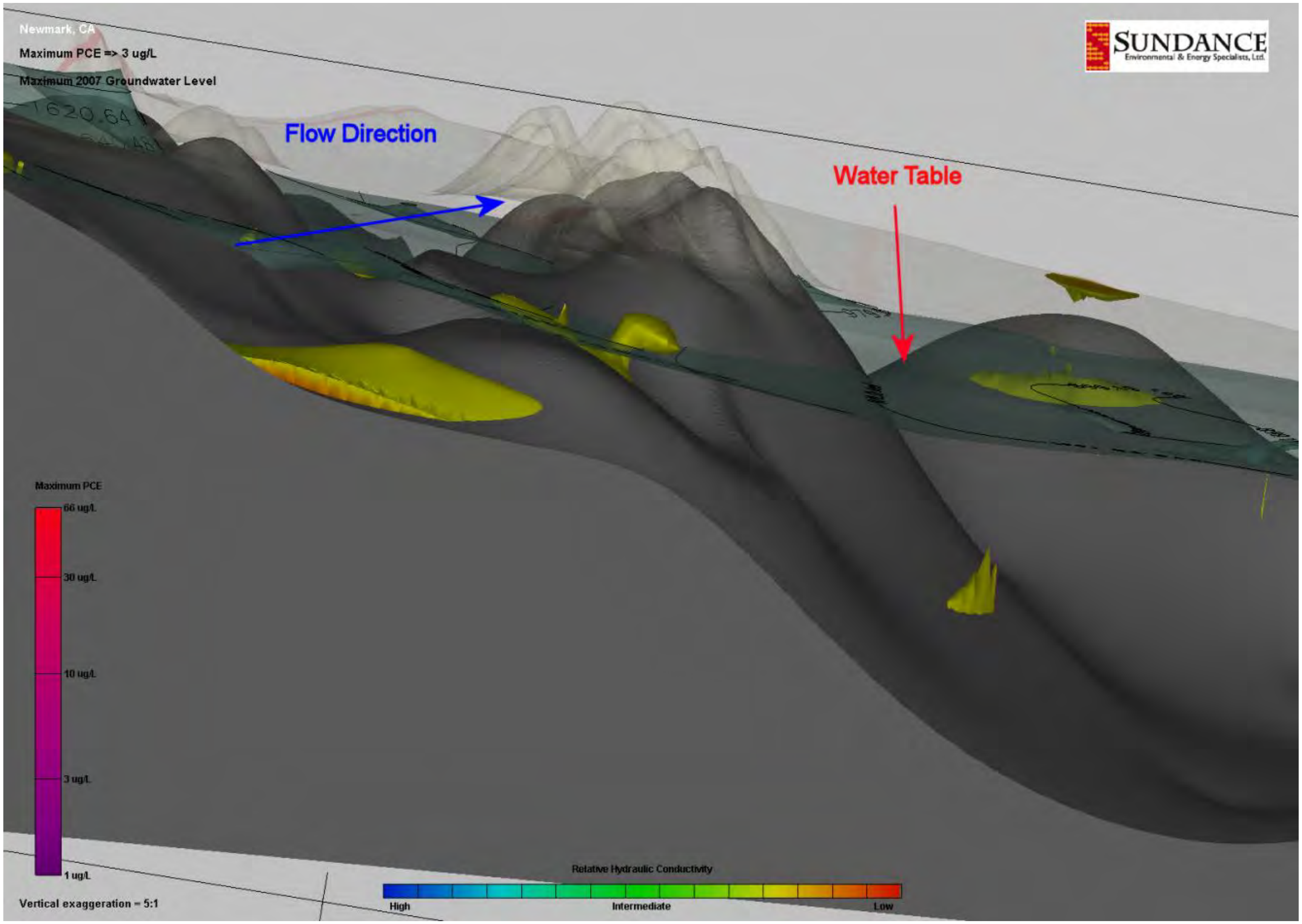


Figure 8.6. Groundwater particle pathlines incorporated into integrated visualization indicate groundwater flow patterns in the Newmark and Muscoy plume areas (Note: the particle pathlines were not generated as estimations of time of groundwater flow, they were generated to corroborate other groundwater flow direction data).

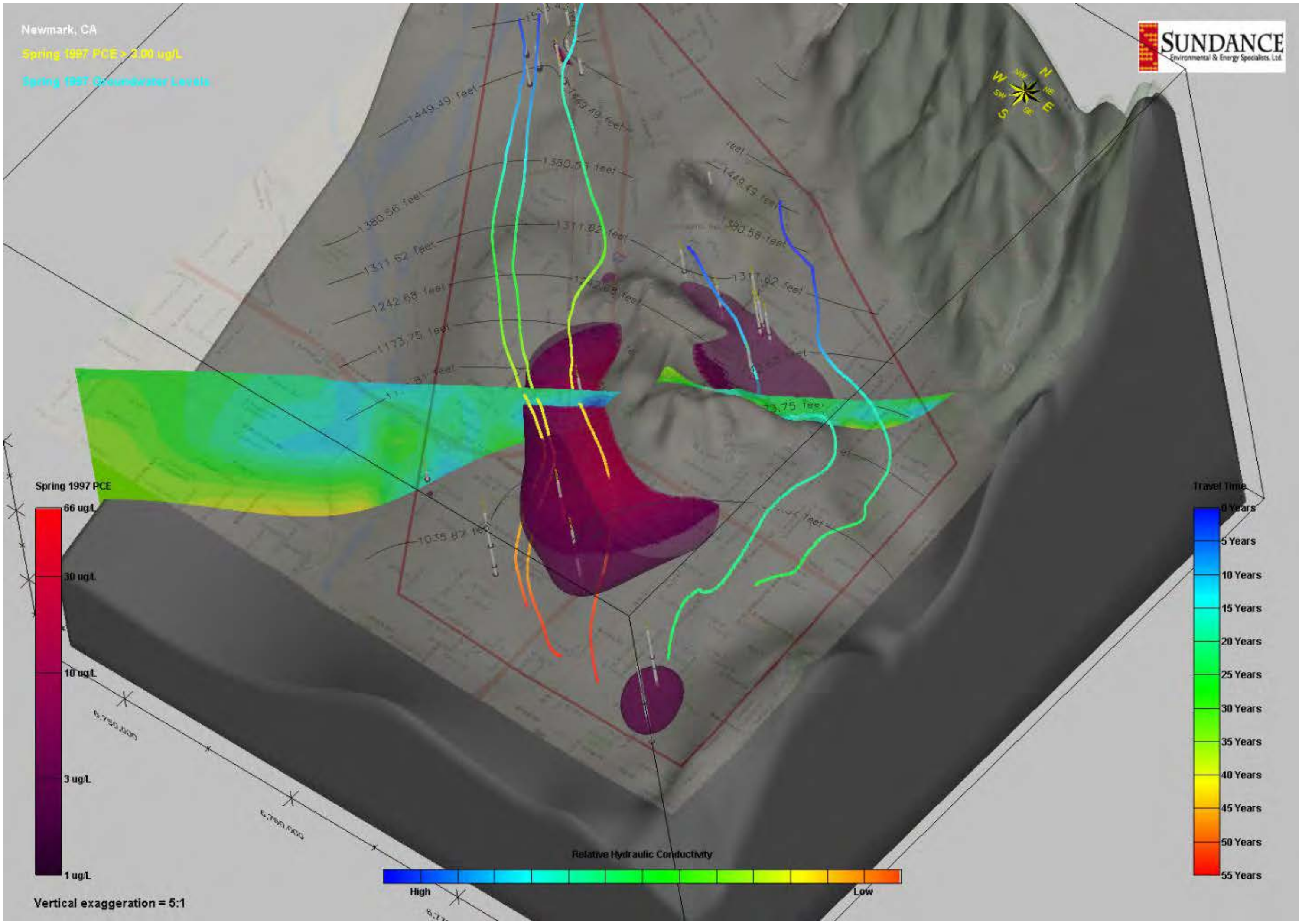


Figure 8.7. Source OU-wide PCE mass at concentrations of 5, 10, and 20 μg/L from 1997-2012.

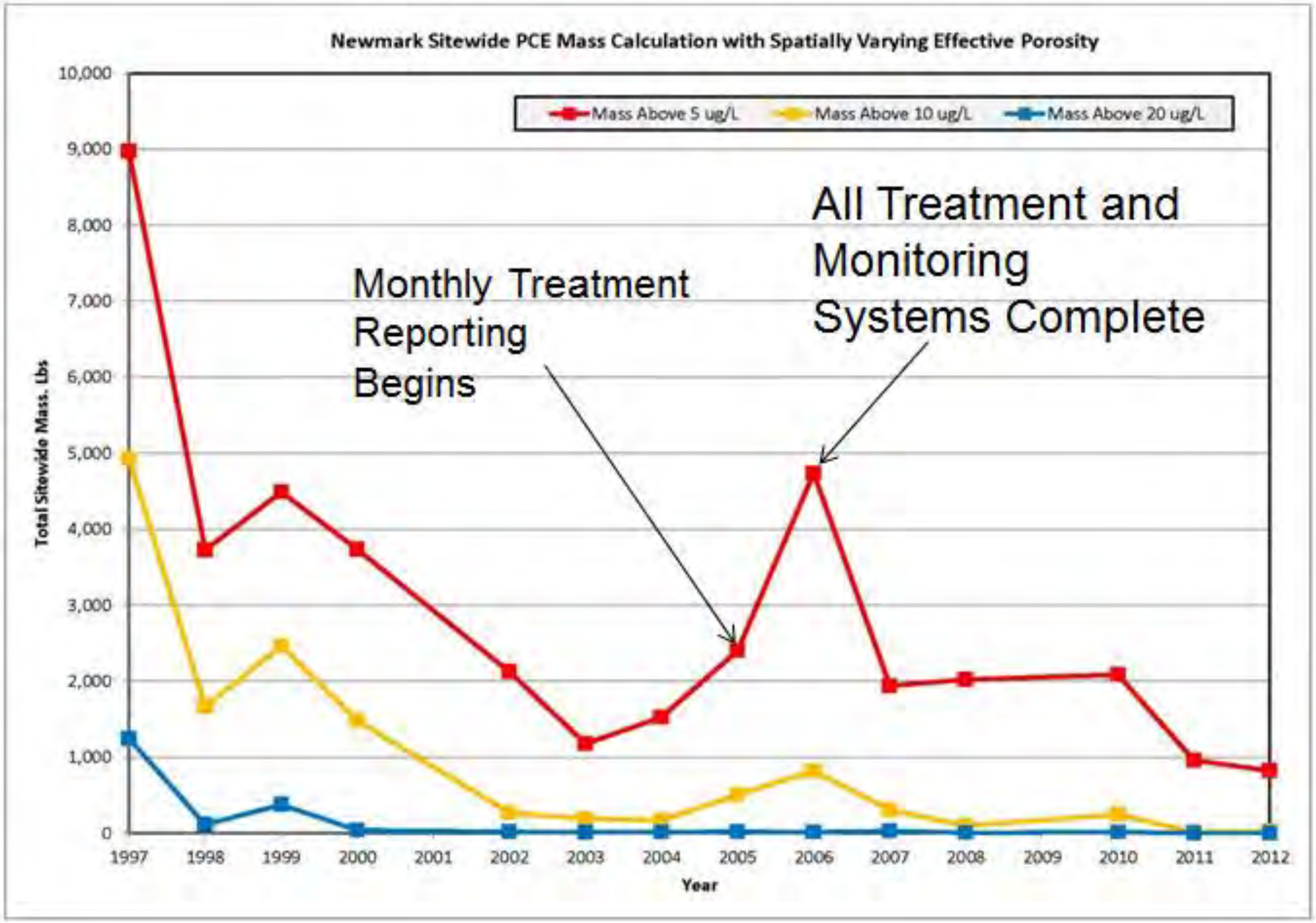


Figure 8.8. Source OU-wide PCE mass at concentrations of 5, 10, and 20 µg/L from 2005-2012 with stable sampling network.

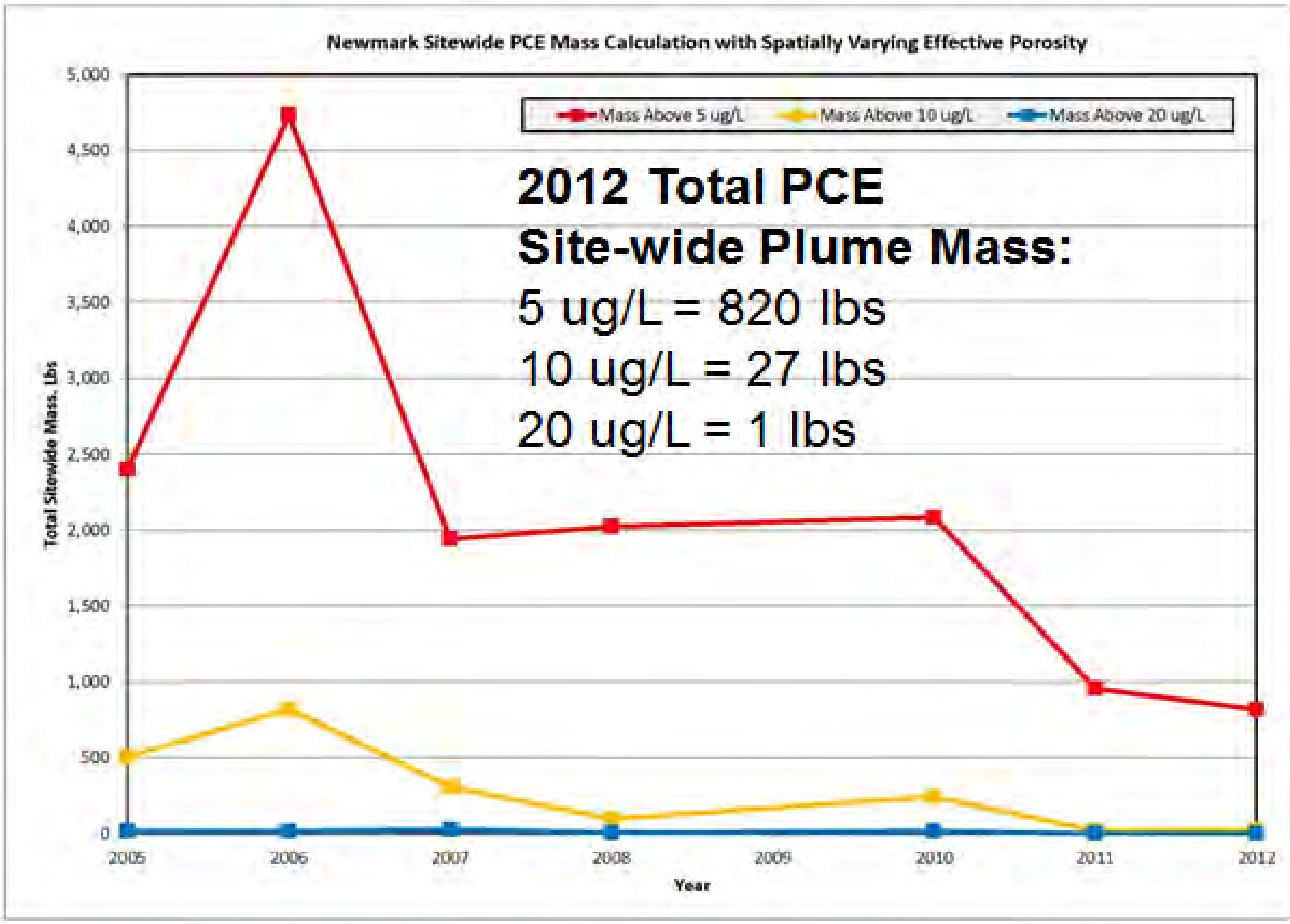


Figure 9.1. PCE Plume in Northwest Source Area visualized at 5 µg/L for the year 1997.

Figure 9.2. PCE Plume in Northwest Source Area visualized at 5 µg/L for the year 2012.

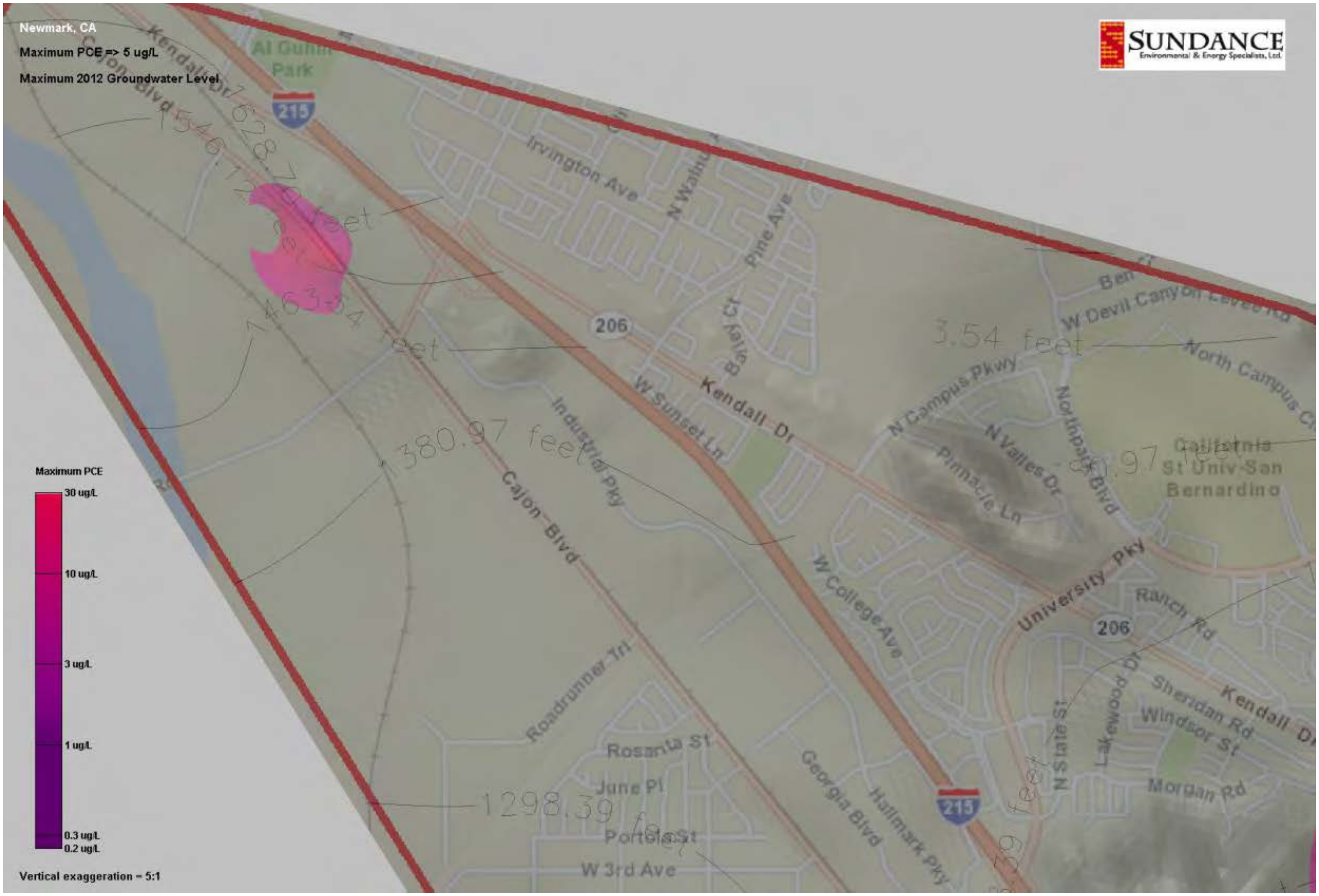


Figure 9.3. Decreases in mass of PCE in Northwest Source Area from 1997-2012.

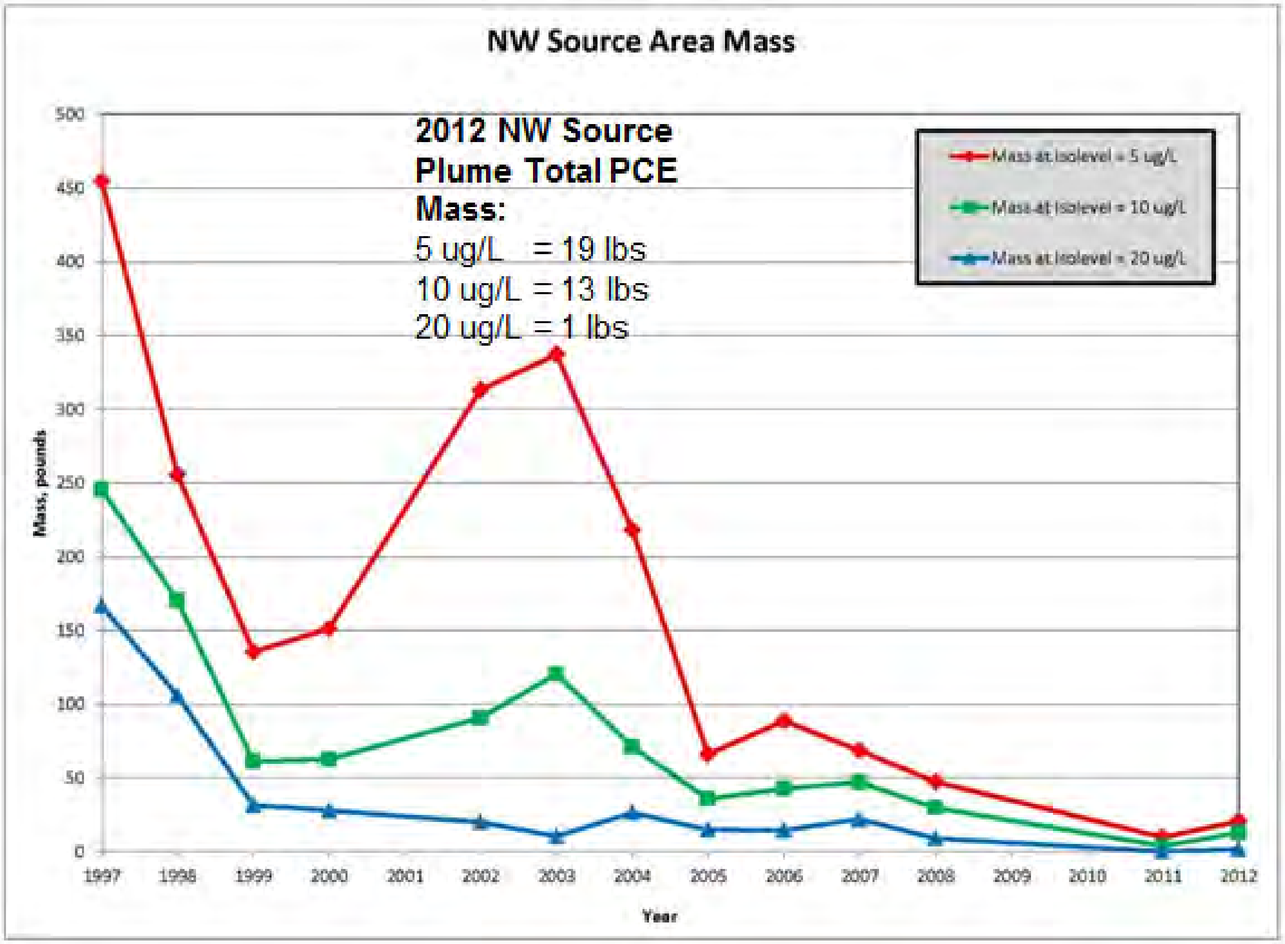


Figure 9.4. Concentrations of PCE detected in monitoring well CJ-10 PCE from 1994-2012.

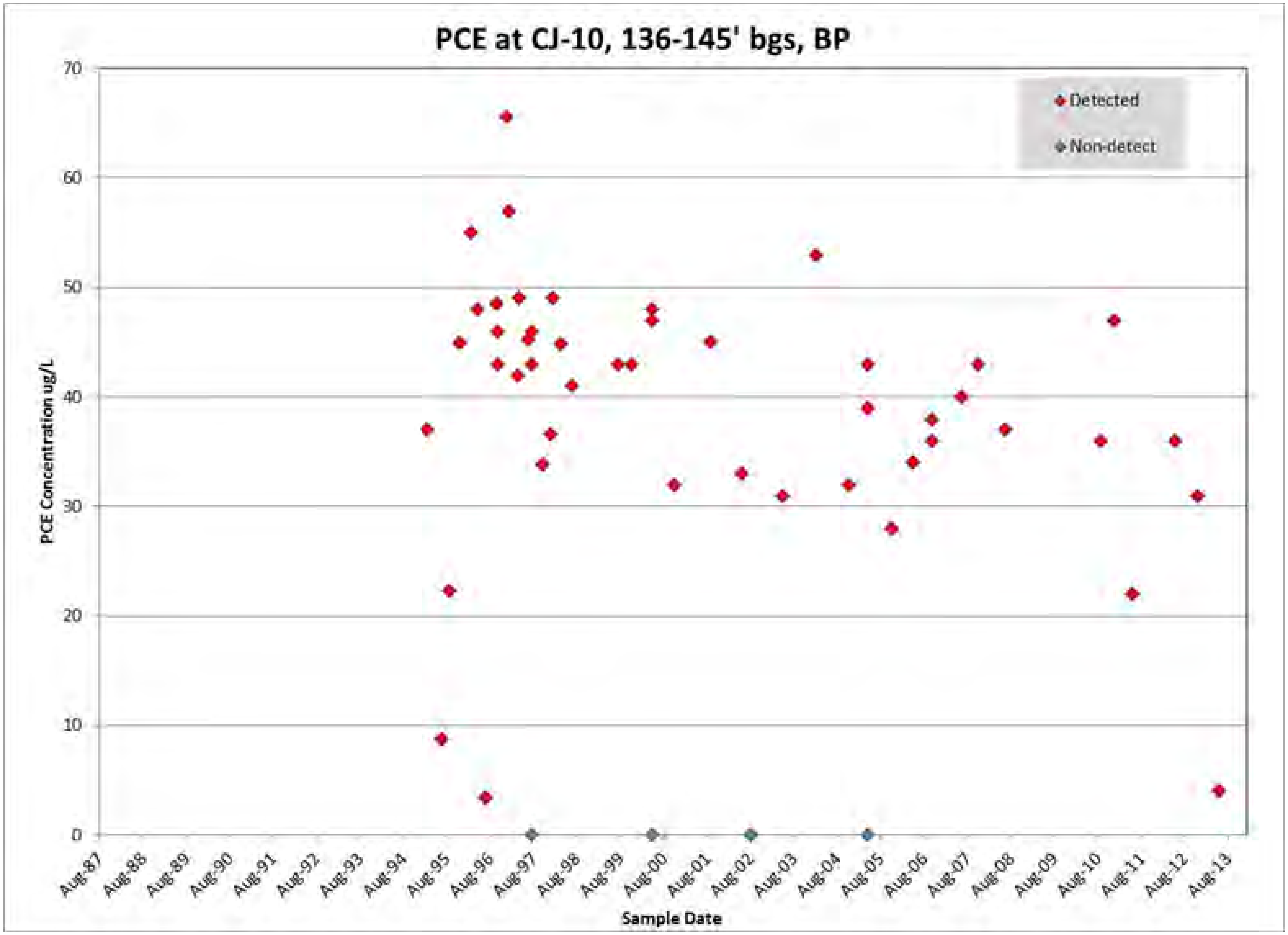


Figure 9.5. Monitoring well CJ-10 located in low K_R deposits (clays to silt) that inhibit movement of PCE.

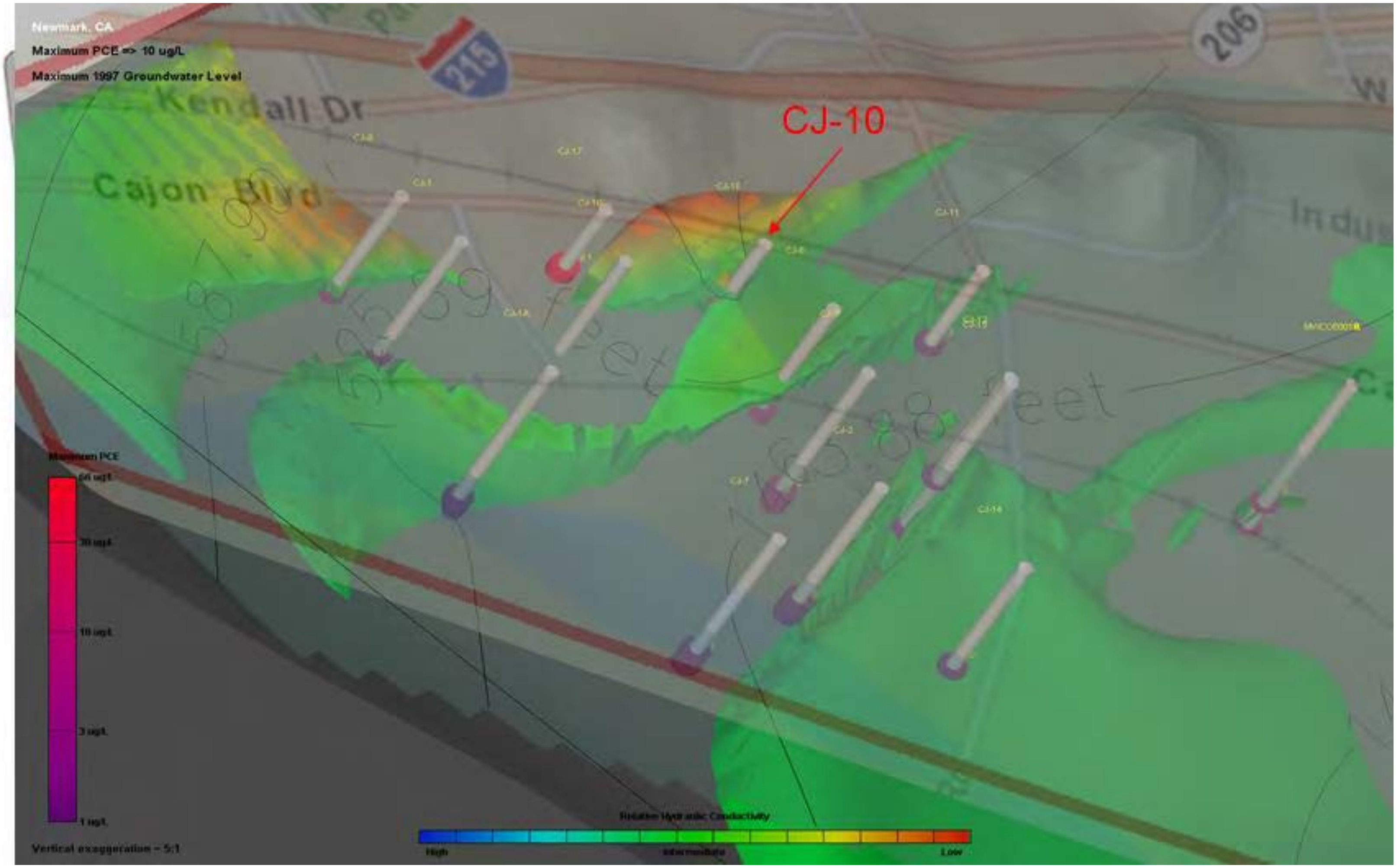


Figure 9.6. Monitoring well CJ-10 located within Former Camp Ono facilities and Cajon Landfill.

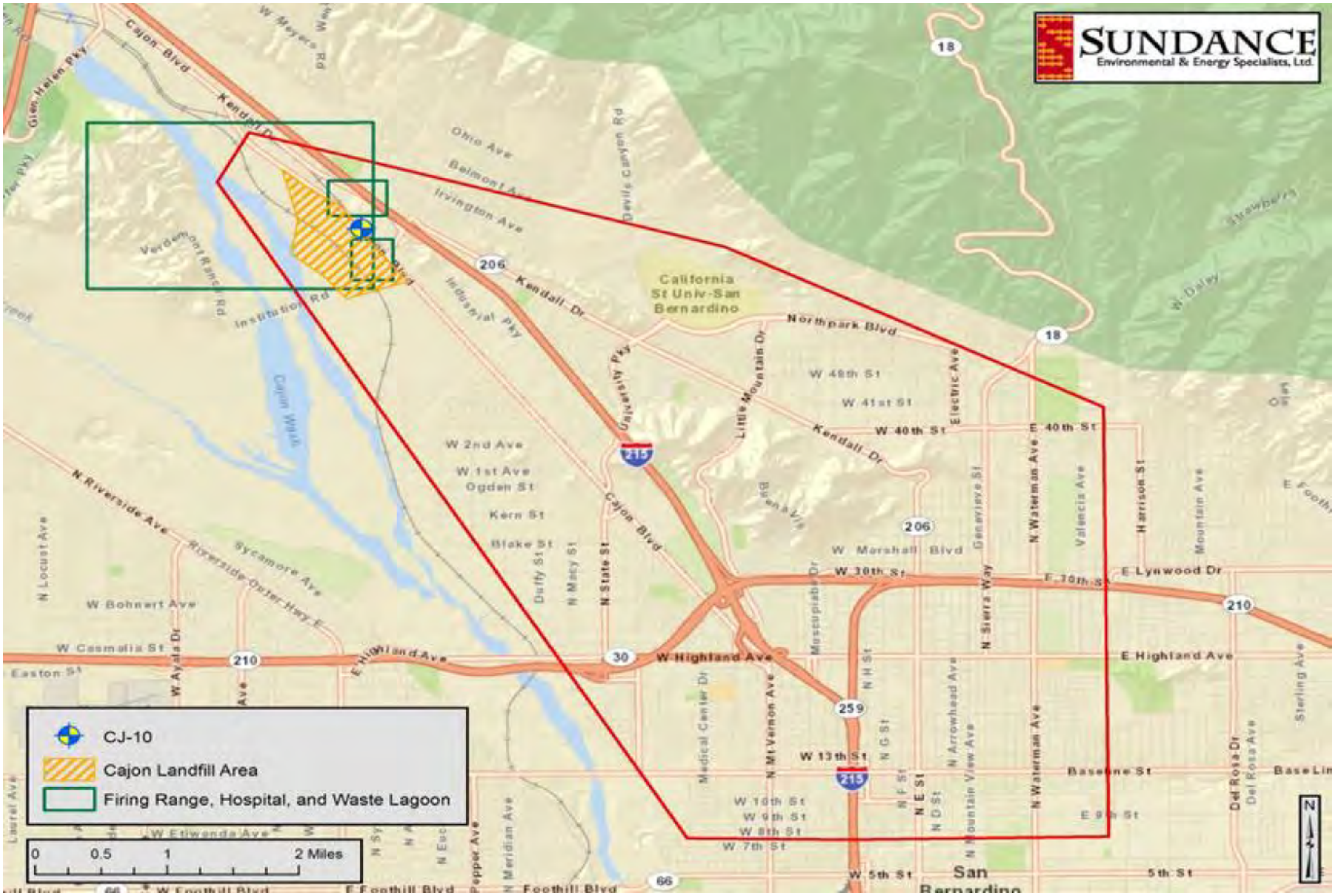


Figure 9.7. Distribution of 1,921 initial sites of potential interest identified for further consideration.

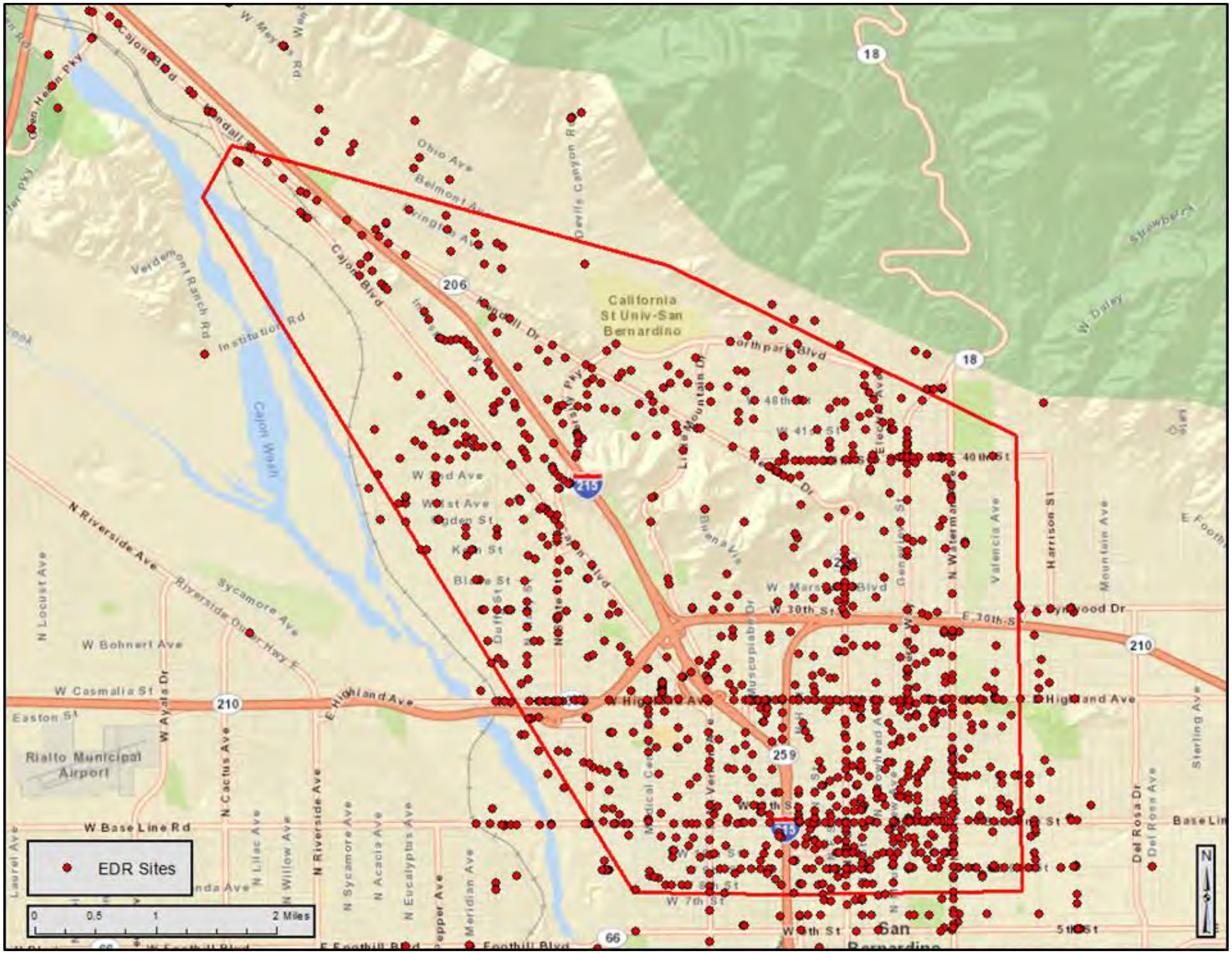


Figure 9.8. Distribution of 46 final sites of potential interest for further consideration.

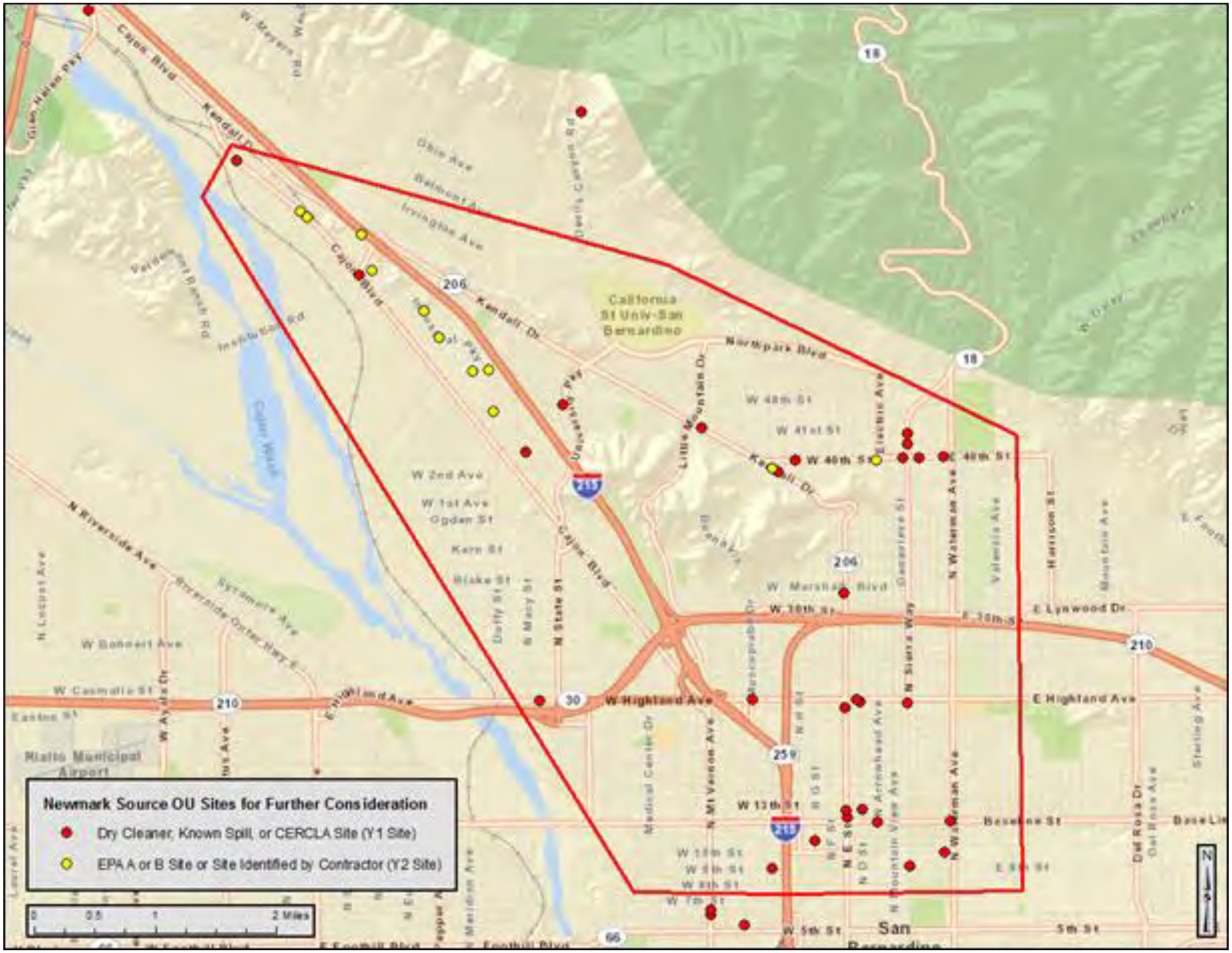


Figure 9.9. Decreases in mass of PCE in Newmark/Muscoy plume from 2005-2012.

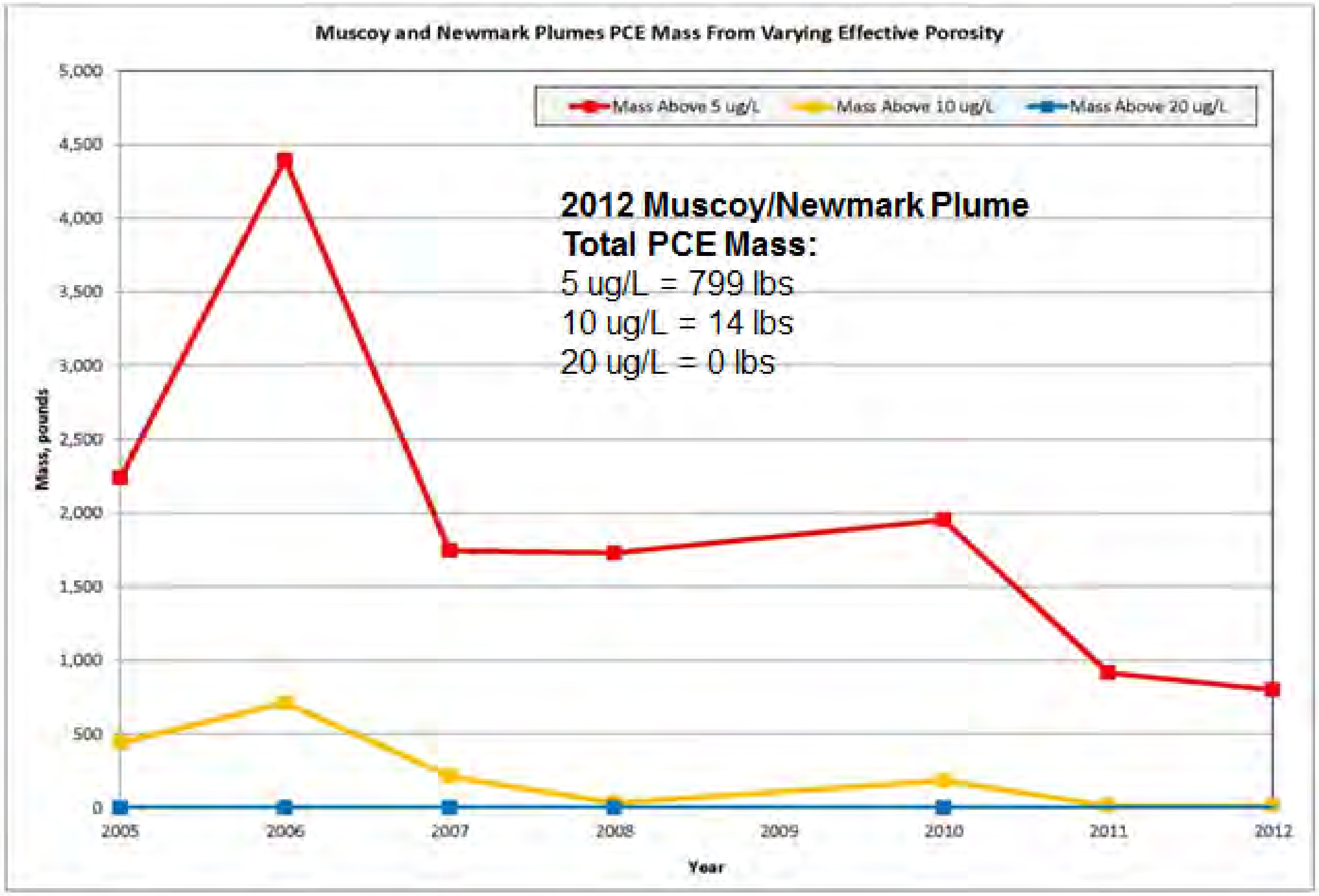


Figure 9.10. Discharge weighted PCE/TCE removal and curve fitting for 19th St. North treatment system discharge from 2005 to 2012.

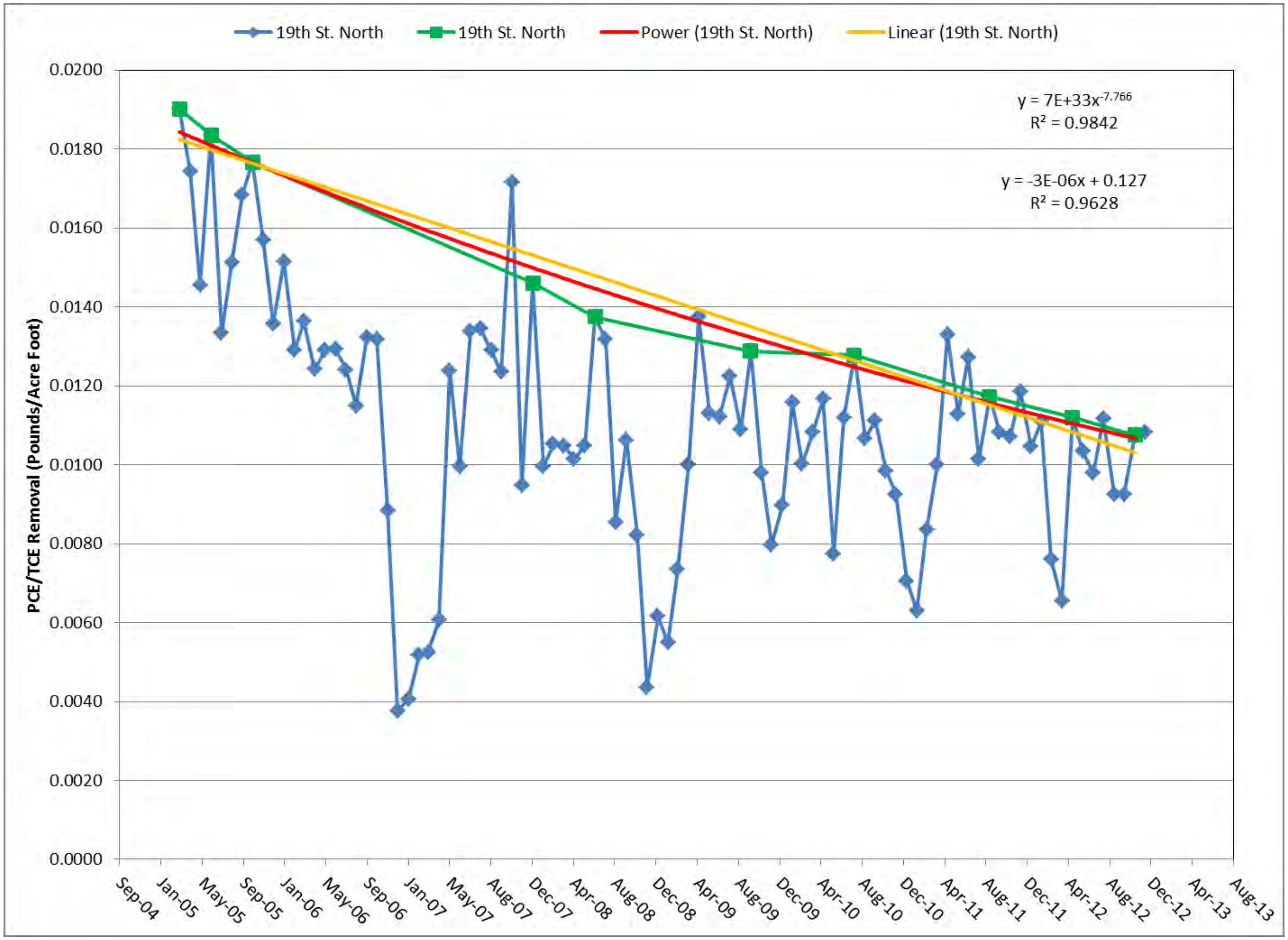


Figure 9.11. Discharge weighted PCE/TCE removal and curve fitting for Newmark treatment system discharge from 2005 to 2012.

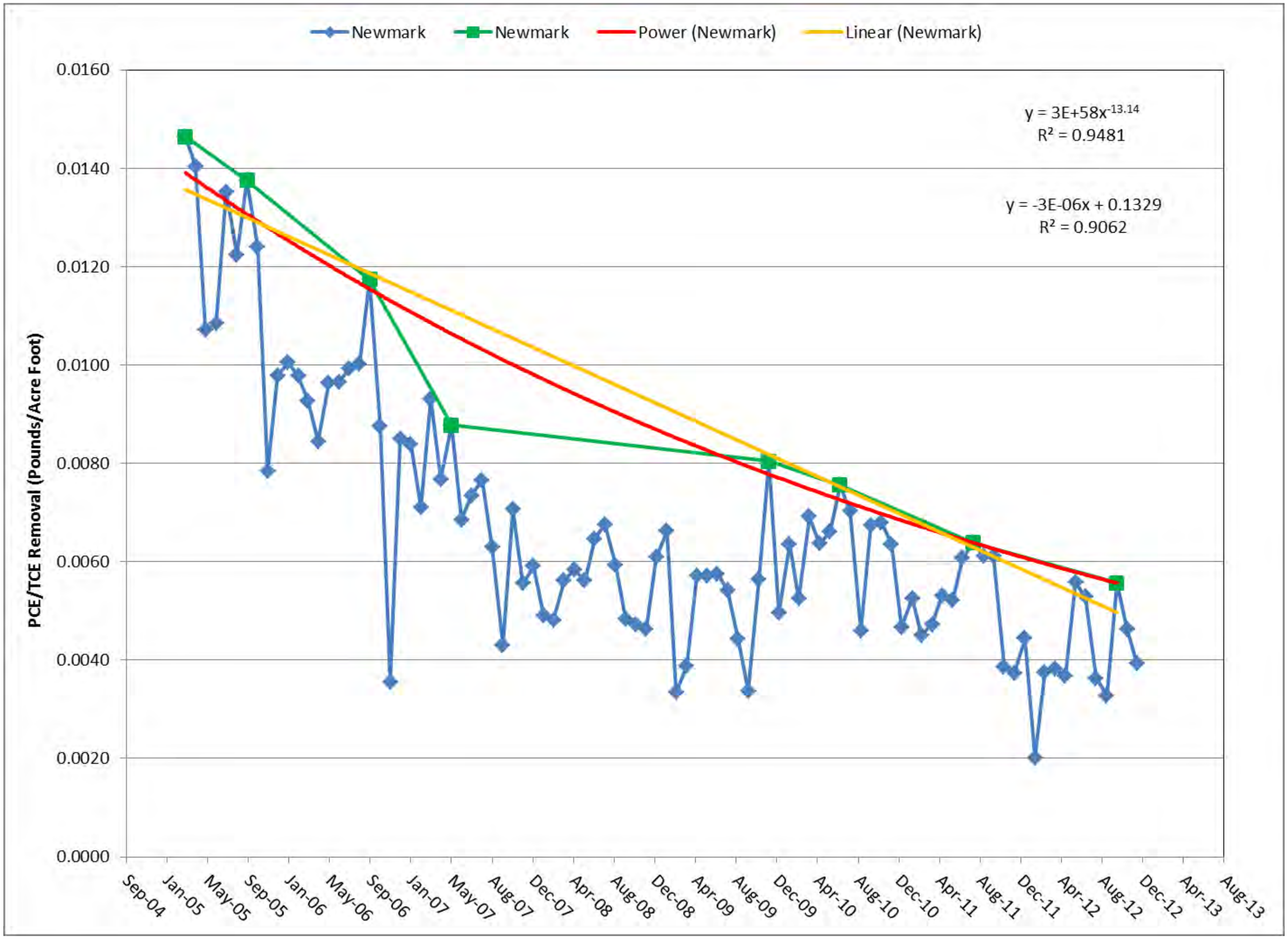


Figure 9.12. Discharge weighted PCE/TCE removal and curve fitting for Waterman treatment system discharge from 2005 to 2012.

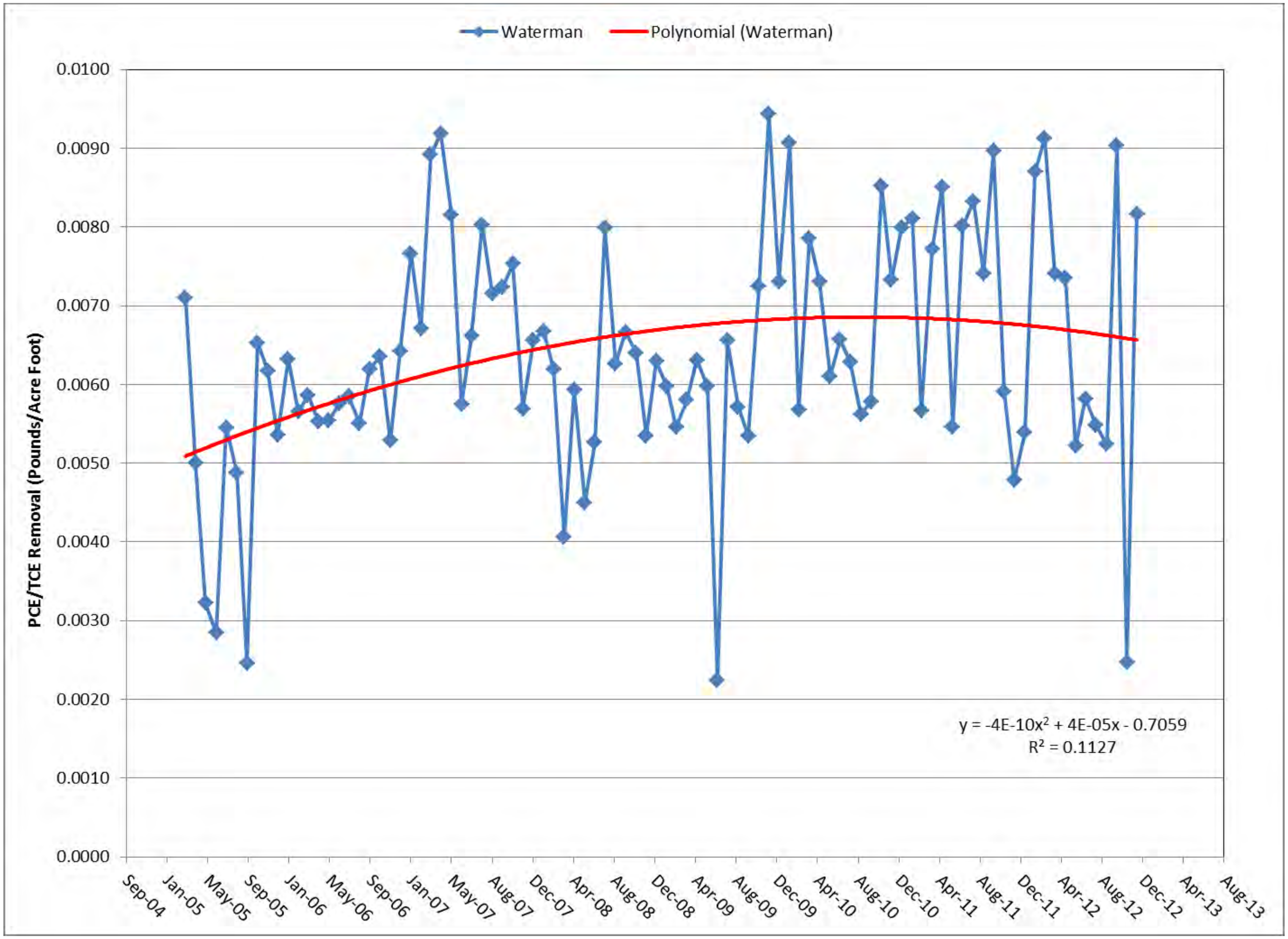


Figure 9.13. Mass (in pounds) of PCE equal to and greater than 5 µg/L for each treatment system as of November 2012.

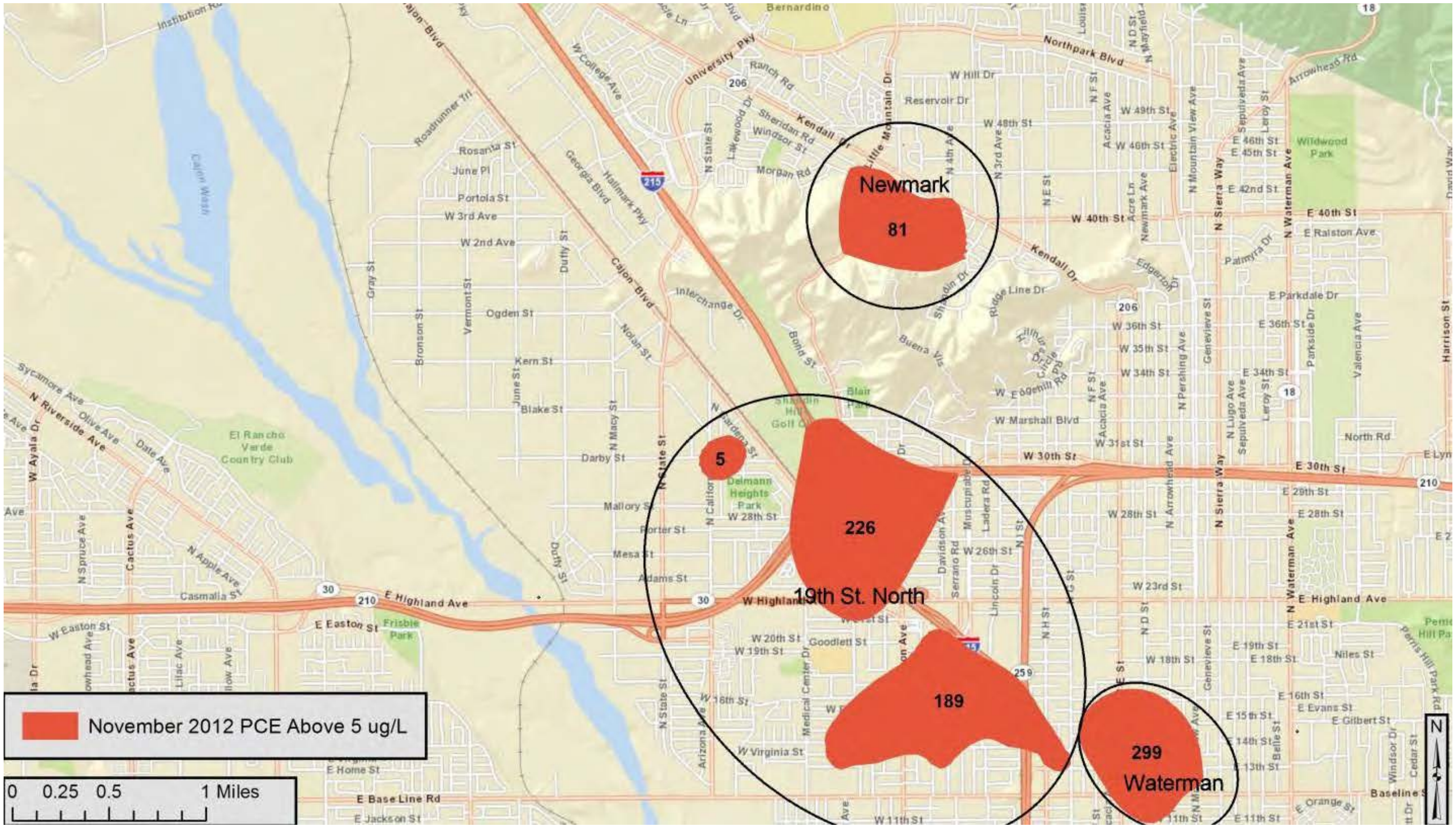


Figure 9.14. Mass (in pounds) of PCE equal to and greater than 7 µg/L for each treatment system as of November 2012.

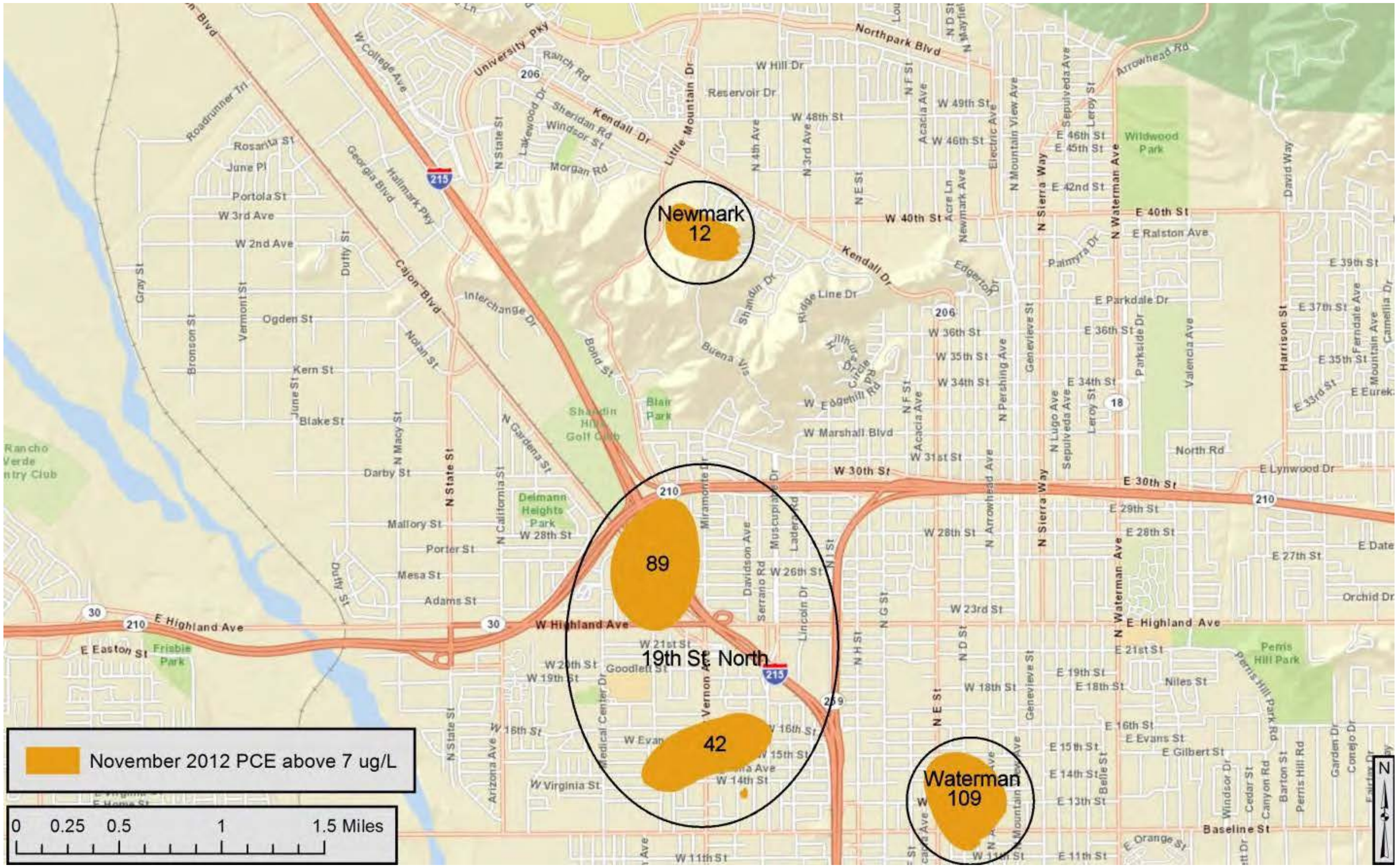


Figure 9.15. Estimate of time to remove PCE to 5 μg/L and below equivalent concentration at 19th St. North treatment system.

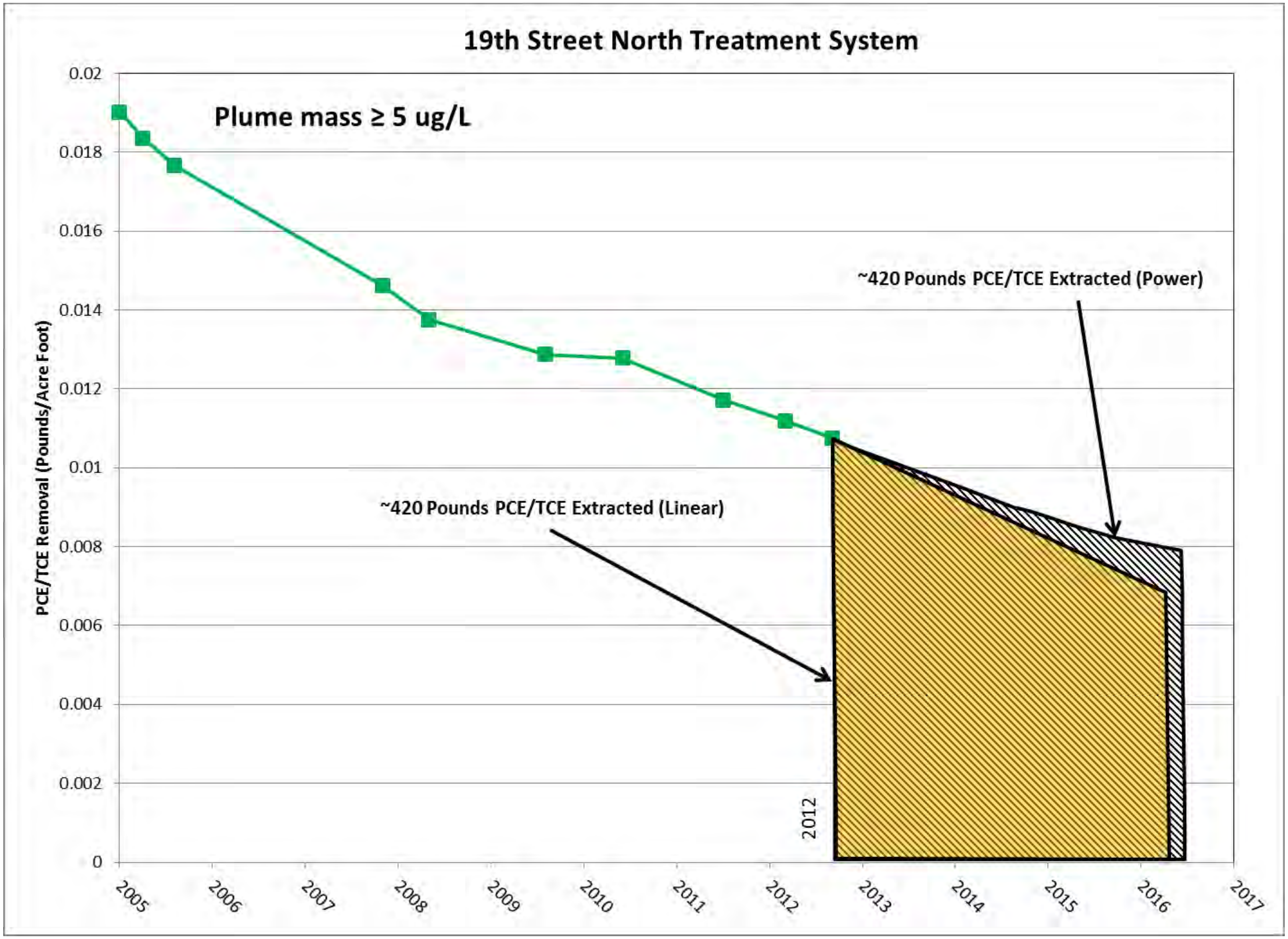


Figure 9.16. Estimate of time to remove PCE to 7 µg/L and below equivalent concentration at 19th St. North treatment system.

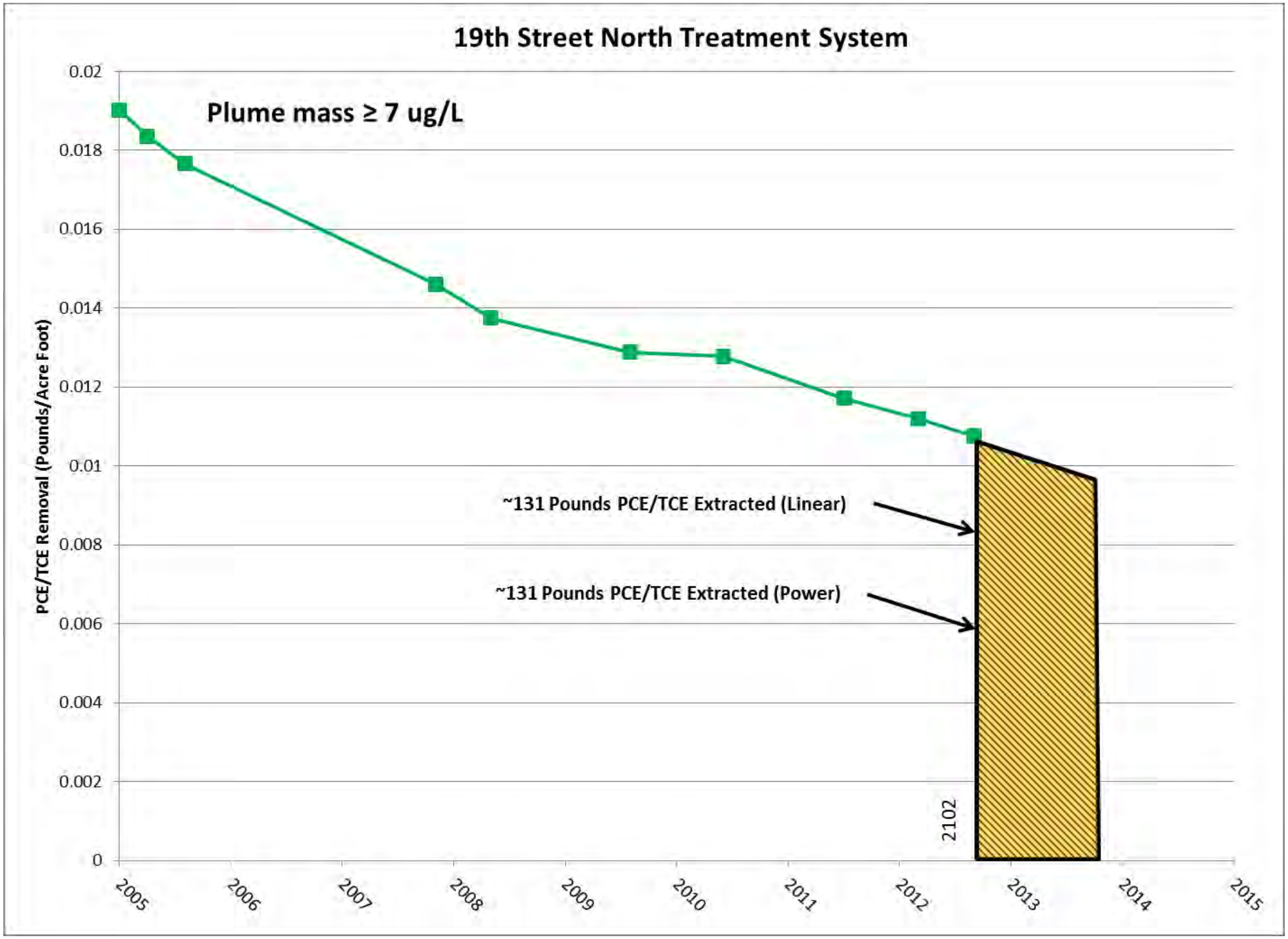


Figure 9.17. Estimate of time to remove PCE to 5 µg/L and below equivalent concentration at Newmark treatment system.

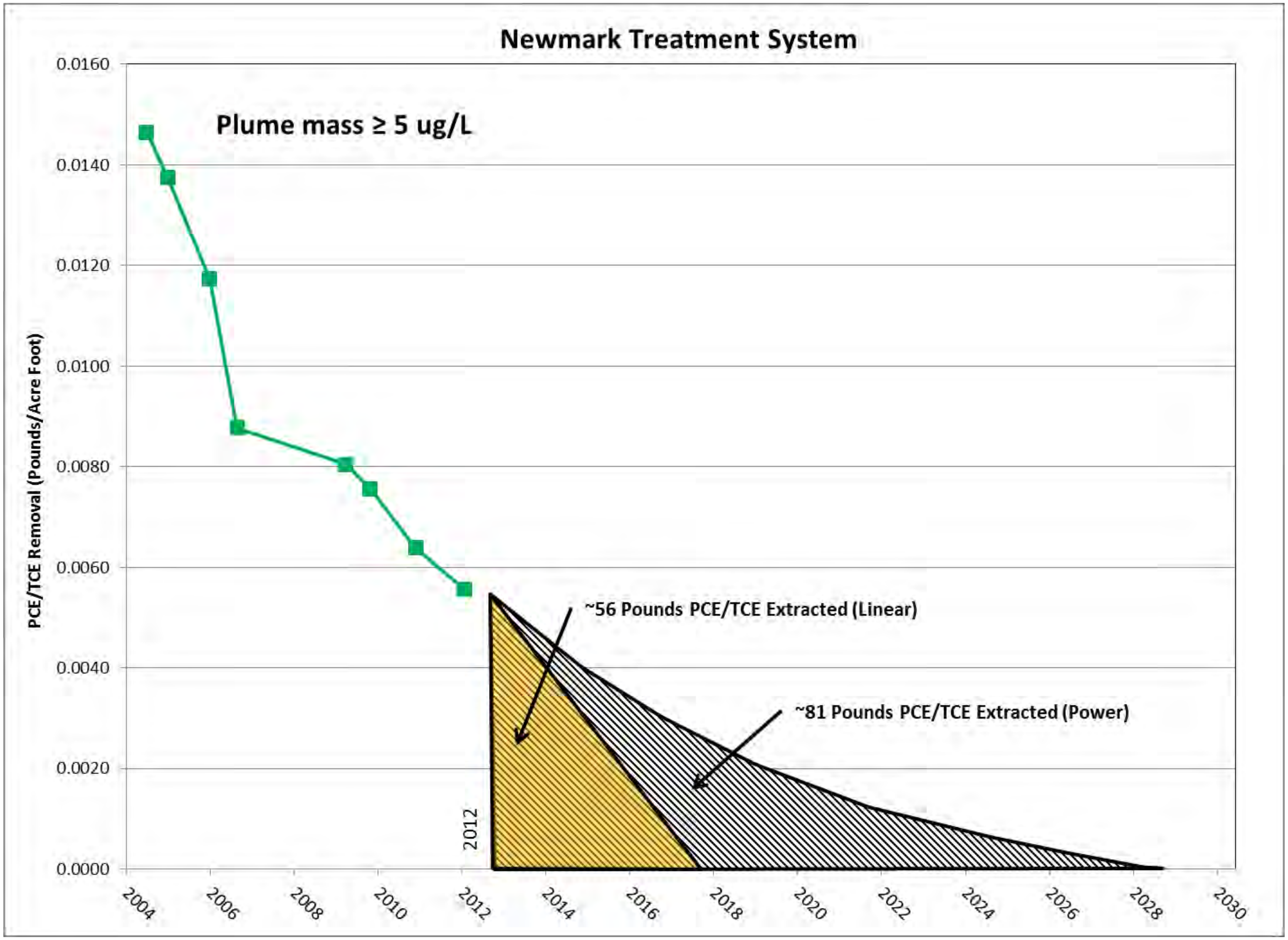


Figure 9.18. Estimate of time to remove PCE to 7 μg/L and below equivalent concentration at Newmark treatment system.

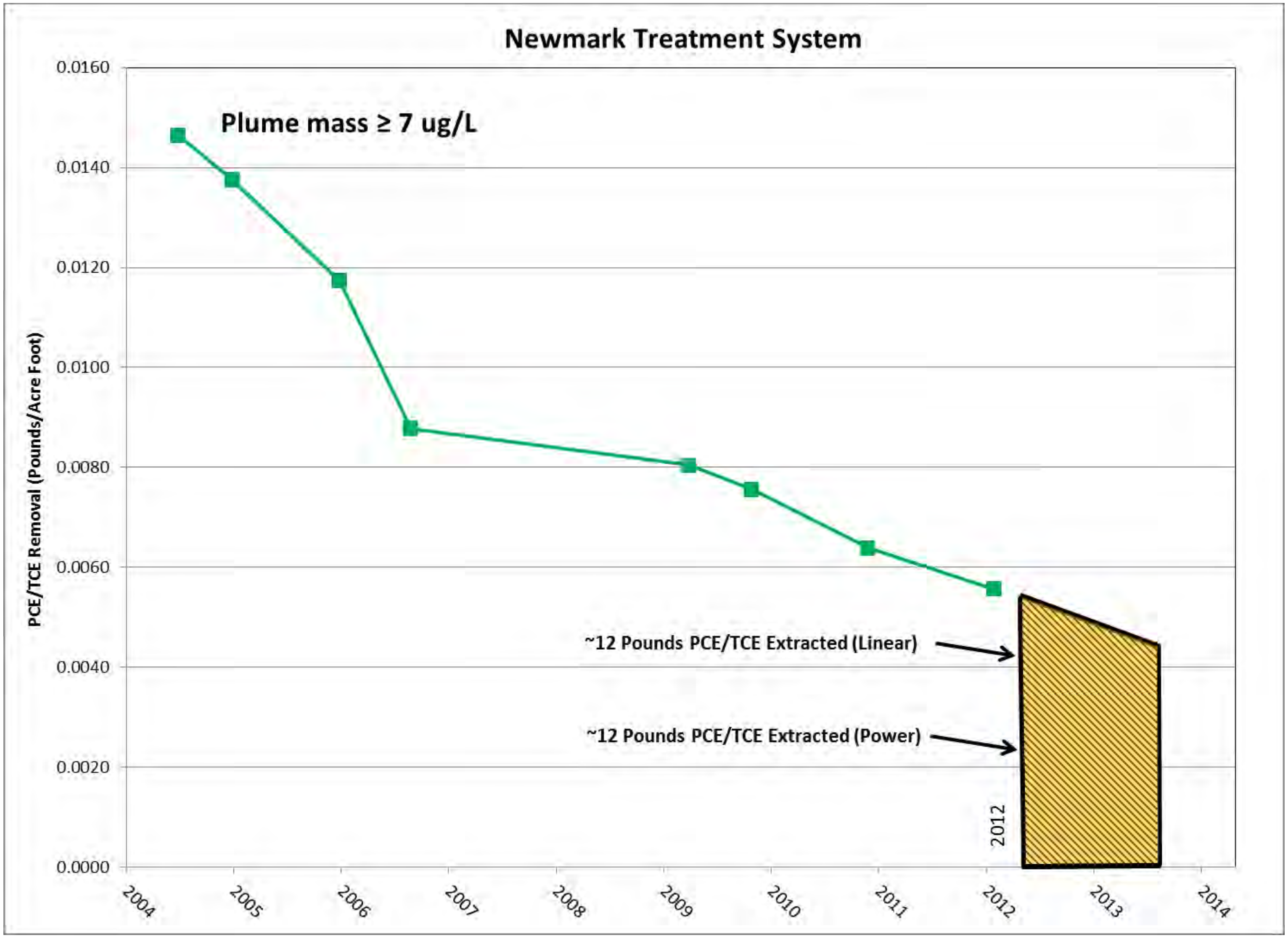


Figure 9.19. Estimate of time to remove PCE to 5 µg/L and below equivalent concentration at Waterman treatment system.

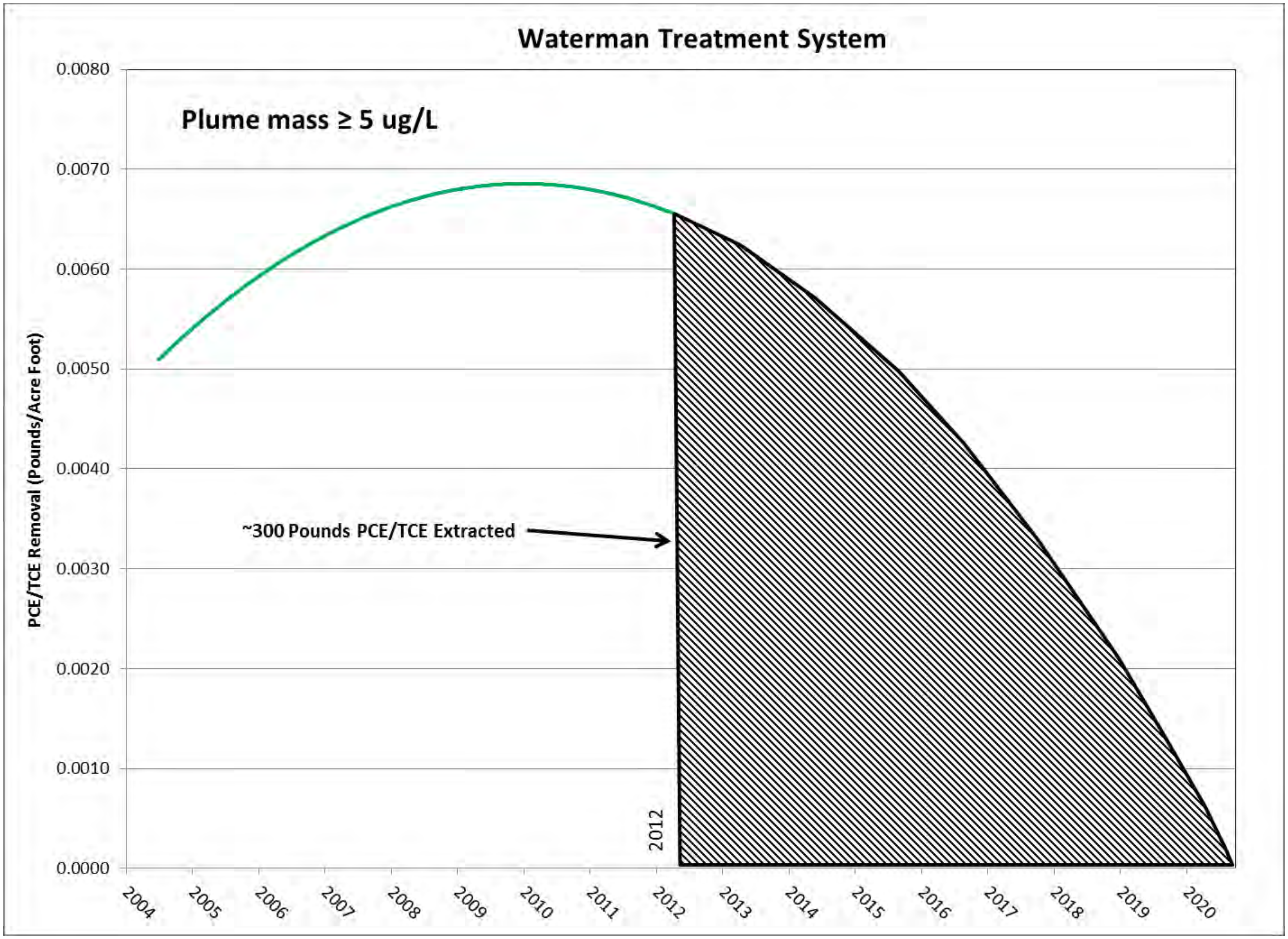


Figure 9.20. Estimate of time to remove PCE to 7 μg/L and below equivalent concentration at Waterman treatment system.

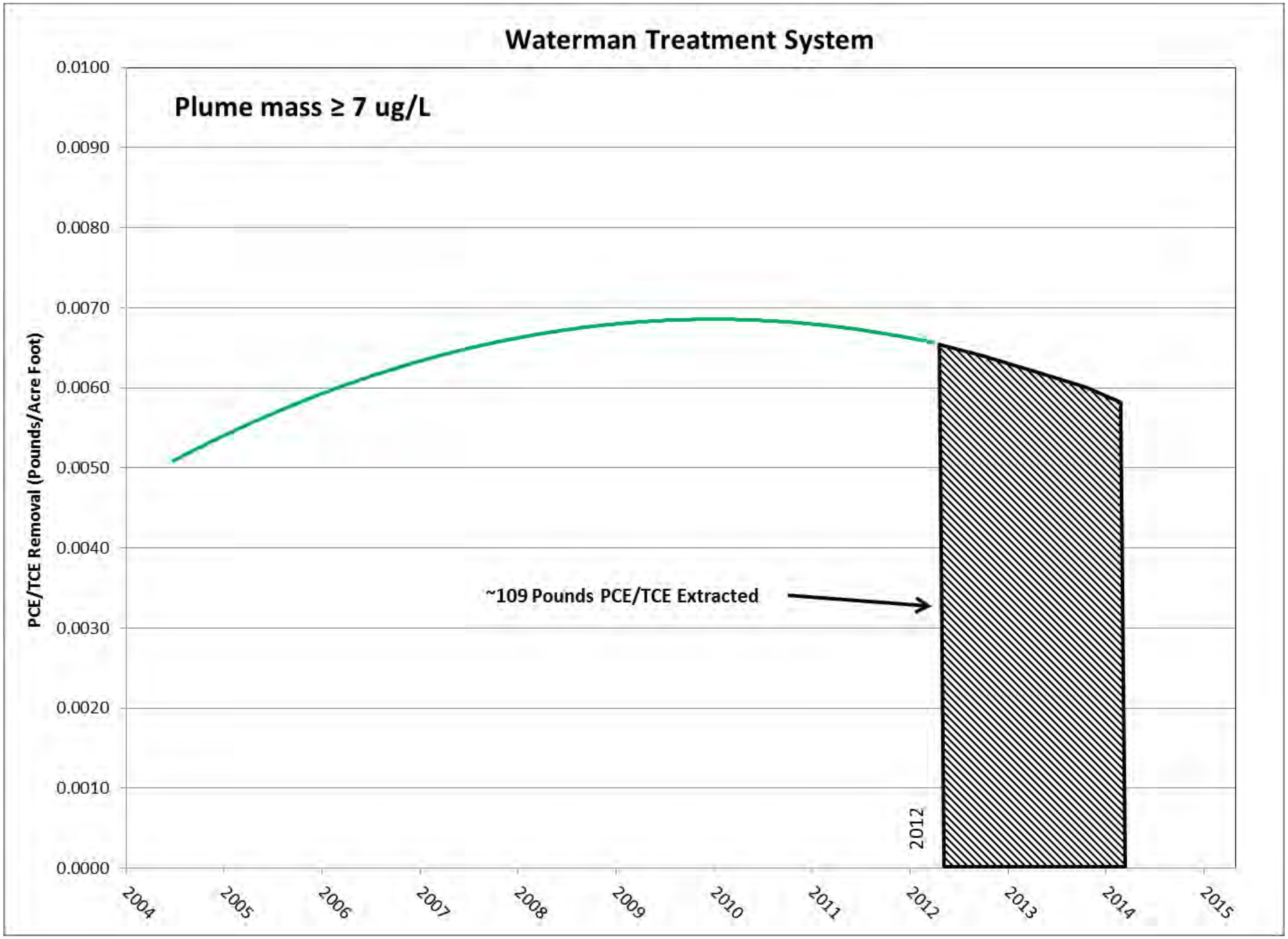


Figure 10.1. Locations of previous soil gas investigation in the Northwest Source Area.

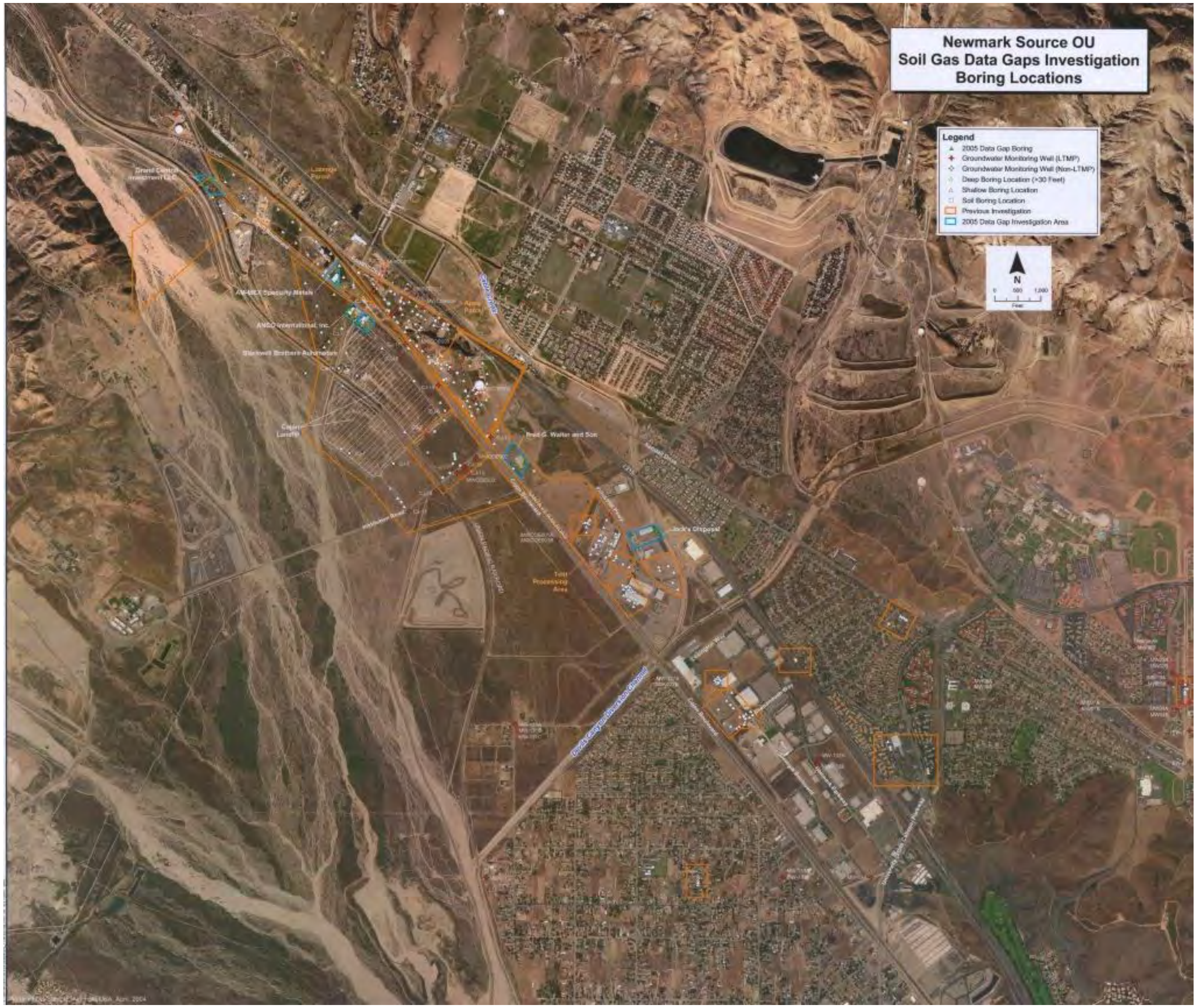
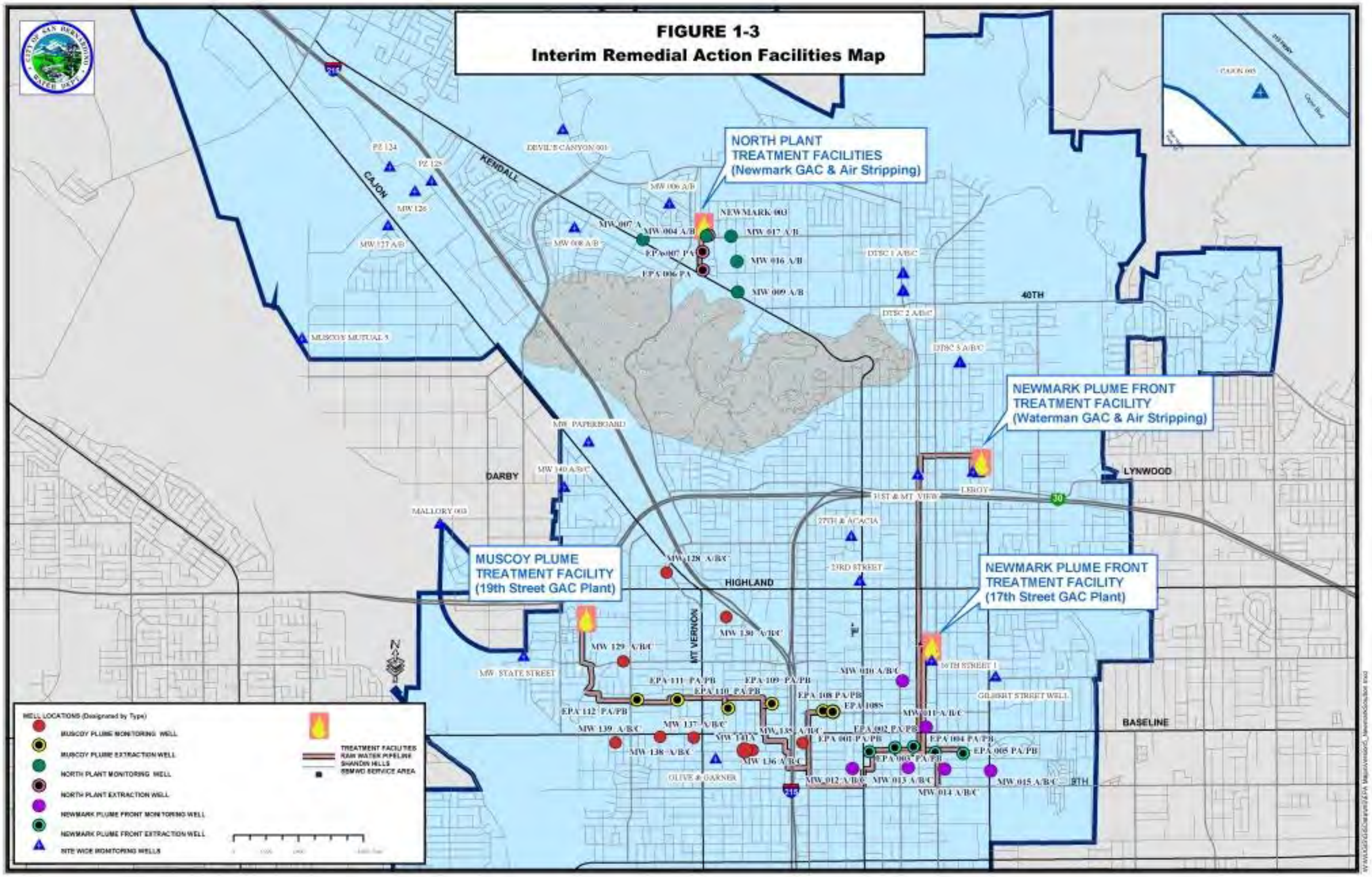


Figure 11.1. Map of interim remedial action treatment plants and extraction well networks.



Appendix A

Time Series Trend Plots

	Flo 4.
Figure A-19	Time series trend plot of PCE at monitoring well CJ-8. Sample collected 234-244 ft below ground surface. Sample type is bladder pump.
Figure A-20	Time series trend plot of PCE at monitoring well CJ-12. Sample collected 246-256 ft below ground surface. Sample type is bailer.
Figure A-21	Time series trend plot of PCE at monitoring well CJ-14. Sample collected 245-255 ft below ground surface. Sample type is bailer.
Figure A-22	Time series trend plot of PCE at monitoring well CJ-16. Sample collected 250-270 ft below ground surface. Sample type is Redi-Flo 2.
Figure A-23	Time series trend plot of PCE at monitoring well MWCOE004. Sample collected 110 ft below ground surface. Sample type is passive diffusion bag.
Figure A-24	Time series trend plot of PCE at monitoring well MWCOE001B. Sample collected 357 ft below ground surface. Sample type is passive diffusion bag.
Figure A-25	Time series trend plot of PCE at monitoring well MW-130B. Sample collected 565 ft below ground surface. Sample type is passive diffusion bag.
Figure A-26	Time series trend plot of PCE at monitoring well MUNI-109. Sample collected 329 ft below ground surface. Sample type is passive diffusion bag.
Figure A-27	Time series trend plot of PCE at monitoring well MW-129B. Sample collected 745 ft below ground surface. Sample type is passive diffusion bag.
Figure A-28	Time series trend plot of PCE at monitoring well MW-127B. Sample collected 441 ft below ground surface. Sample type is passive diffusion bag.
Figure A-29	Time series trend plot of PCE at monitoring well MWCOE001A. Sample collected 299 ft below ground surface. Sample type is passive diffusion bag.
Figure A-30	Time series trend plot of PCE at monitoring well MW-08B. Sample collected 480 ft below ground surface. Sample type is passive diffusion bag.
Figure A-31	Time series trend plot of PCE at monitoring well MW-02B. Sample collected 380 ft below ground surface. Sample type is passive diffusion bag.
Figure A-32	Time series trend plot of PCE at monitoring well MW-05B. Sample collected 442 ft below ground surface. Sample type is passive diffusion bag.
Figure A-33	Time series trend plot of PCE at monitoring well MW-16B. Sample collected 440 ft below ground surface. Sample type is passive diffusion bag.
Figure A-34	Time series trend plot of PCE at monitoring well MW-03B. Sample collected 350 ft below ground surface. Sample type is passive diffusion bag.
Figure A-35	Time series trend plot of PCE at monitoring well MW-04B. Sample collected 390 ft below ground surface. Sample type is passive diffusion bag.
Figure A-36	Time series trend plot of PCE at monitoring well MW-07B. Sample collected 496 ft below ground surface. Sample type is

	passive diffusion bag.
Figure A-37	Time series trend plot of PCE at monitoring well MW-09B. Sample collected 355 ft below ground surface. Sample type is passive diffusion bag.
Figure A-38	Time series trend plot of PCE at monitoring well MW-17B. Sample collected 410 ft below ground surface. Sample type is passive diffusion bag.
Figure A-39	Time series trend plot of PCE at monitoring well CJ-13. Sample collected 245-255 ft below ground surface. Sample type is bailer.
Figure A-40	Time series trend plot of PCE at monitoring well MW07A. Sample collected 315 ft below ground surface. Sample type is passive diffusion bag.
Figure A-41	Time series trend plot of PCE at monitoring well EW-6PA. Sample collected 240 ft below ground surface. Sample type is piezometer.
Figure A-42	Time series trend plot of PCE at monitoring well EW-7PA. Sample collected 330 ft below ground surface. Sample type is piezometer.
Figure A-43	Time series trend plot of PCE at well MUNI-07C. Sample collected 389-399 ft below ground surface. Sample type is well head spigot.
Figure A-44	Time series trend plot of PCE at well MUNI-11C. Sample collected 492-502 ft below ground surface. Sample type is well head spigot.
Figure A-45	Time series trend plot of PCE at well MUNI-09B. Sample collected 252-262 ft below ground surface. Sample type is well head spigot.
Figure A-46	Time series trend plot of PCE at well MUNI-09C. Sample collected 418-428 ft below ground surface. Sample type is well head spigot.
Figure A-47	Time series trend plot of PCE at well MUNI-11A. Sample collected 350-360 ft below ground surface. Sample type is well head spigot.
Figure A-48	Time series trend plot of TCE at monitoring well CJ-1. Sample collected 276-316 ft below ground surface. Sample type is well Redi-Flo 4.
Figure A-49	Time series trend plot of TCE at monitoring well CJ-3. Sample collected 290-330 ft below ground surface. Sample type is Redi-Flo 4.
Figure A-50	Time series trend plot of TCE at monitoring well CJ-6. Sample collected 240-280 ft below ground surface. Sample type is Redi-Flo 2.
Figure A-51	Time series trend plot of TCE at monitoring well CJ-8. Sample collected 234-244 ft below ground surface. Sample type is bladder pump.
Figure A-52	Time series trend plot of TCE at monitoring well CJ-10. Sample collected 136-145 ft below ground surface. Sample type is bladder pump.
Figure A-53	Time series trend plot of TCE at monitoring well CJ-11. Sample collected 179-189 ft below ground surface. Sample type is bladder pump.
Figure A-54	Time series trend plot of TCE at monitoring well CJ-15. Sample collected 355-378 ft below ground surface. Sample type is Redi-

	Flo 4.
Figure A-57	Time series trend plot of TCE at monitoring well MWCOE005. Sample collected 150 ft below ground surface. Sample type is passive diffusion bag.
Figure A-55	Time series trend plot of TCE at monitoring well CJ-16. Sample collected 250-270 ft below ground surface. Sample type is Redi-Flo 2.
Figure A-56	Time series trend plot of TCE at monitoring well CJ-17. Sample collected 139-159 ft below ground surface. Sample type is Redi-Flo 2.
Figure A-58	Time series trend plot of TCE at monitoring well MWCOE006. Sample collected 108 ft below ground surface. Sample type is passive diffusion bag.
Figure A-59	Time series trend plot of TCE at monitoring well EW-6A. Sample collected 230-250 ft below ground surface. Sample type is piezometer.
Figure A-60	Time series trend plot of TCE at monitoring well EW-7A. Sample collected 320-340 ft below ground surface. Sample type is piezometer.
Figure A-61	Time series trend plot of TCE at monitoring well MW02B. Sample collected 380 ft below ground surface. Sample type is passive diffusion bag.
Figure A-62	Time series trend plot of TCE at monitoring well MW03B. Sample collected 350 ft below ground surface. Sample type is passive diffusion bag.
Figure A-63	Time series trend plot of TCE at monitoring well MW04B. Sample collected 390 ft below ground surface. Sample type is passive diffusion bag.
Figure A-64	Time series trend plot of TCE at monitoring well MW05B. Sample collected 442 ft below ground surface. Sample type is passive diffusion bag.
Figure A-65	Time series trend plot of TCE at monitoring well MW06B. Sample collected 327 ft below ground surface. Sample type is passive diffusion bag.
Figure A-66	Time series trend plot of TCE at monitoring well MW07A. Sample collected 315 ft below ground surface. Sample type is passive diffusion bag.
Figure A-67	Time series trend plot of TCE at monitoring well MW07B. Sample collected 496 ft below ground surface. Sample type is passive diffusion bag.
Figure A-68	Time series trend plot of TCE at monitoring well MW08B. Sample collected 480 ft below ground surface. Sample type is passive diffusion bag.
Figure A-69	Time series trend plot of TCE at monitoring well MW09B. Sample collected 355 ft below ground surface. Sample type is passive diffusion bag.
Figure A-70	Time series trend plot of TCE at monitoring well MW16B. Sample collected 440 ft below ground surface. Sample type is passive diffusion bag.
Figure A-71	Time series trend plot of TCE at monitoring well MW17B. Sample collected 410 ft below ground surface. Sample type is passive diffusion bag.

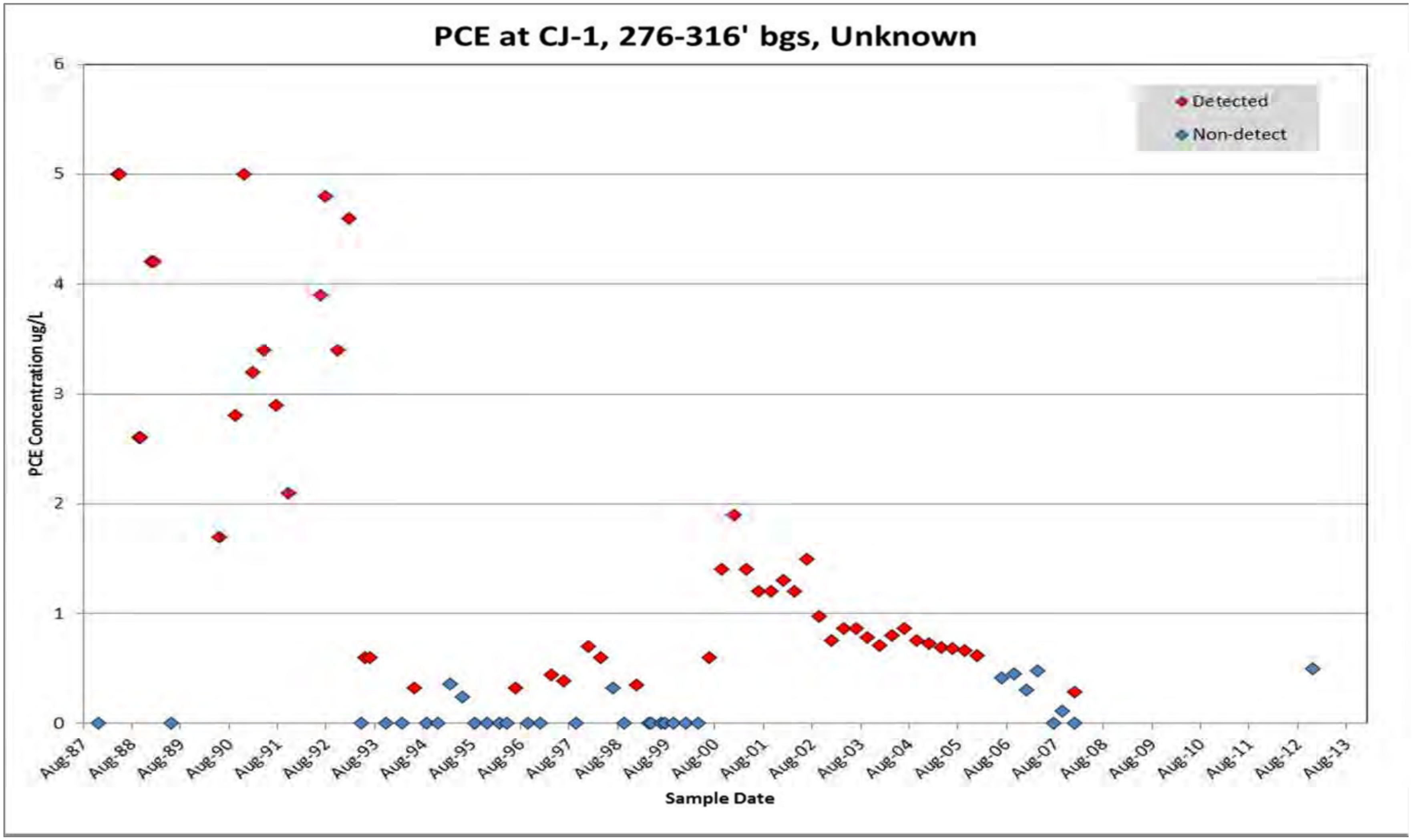


Figure A-1. Time series trend plot of PCE at monitoring well CJ-1. Sample collected 276-316 ft below ground surface. Sample type is Redi-Flo 4.

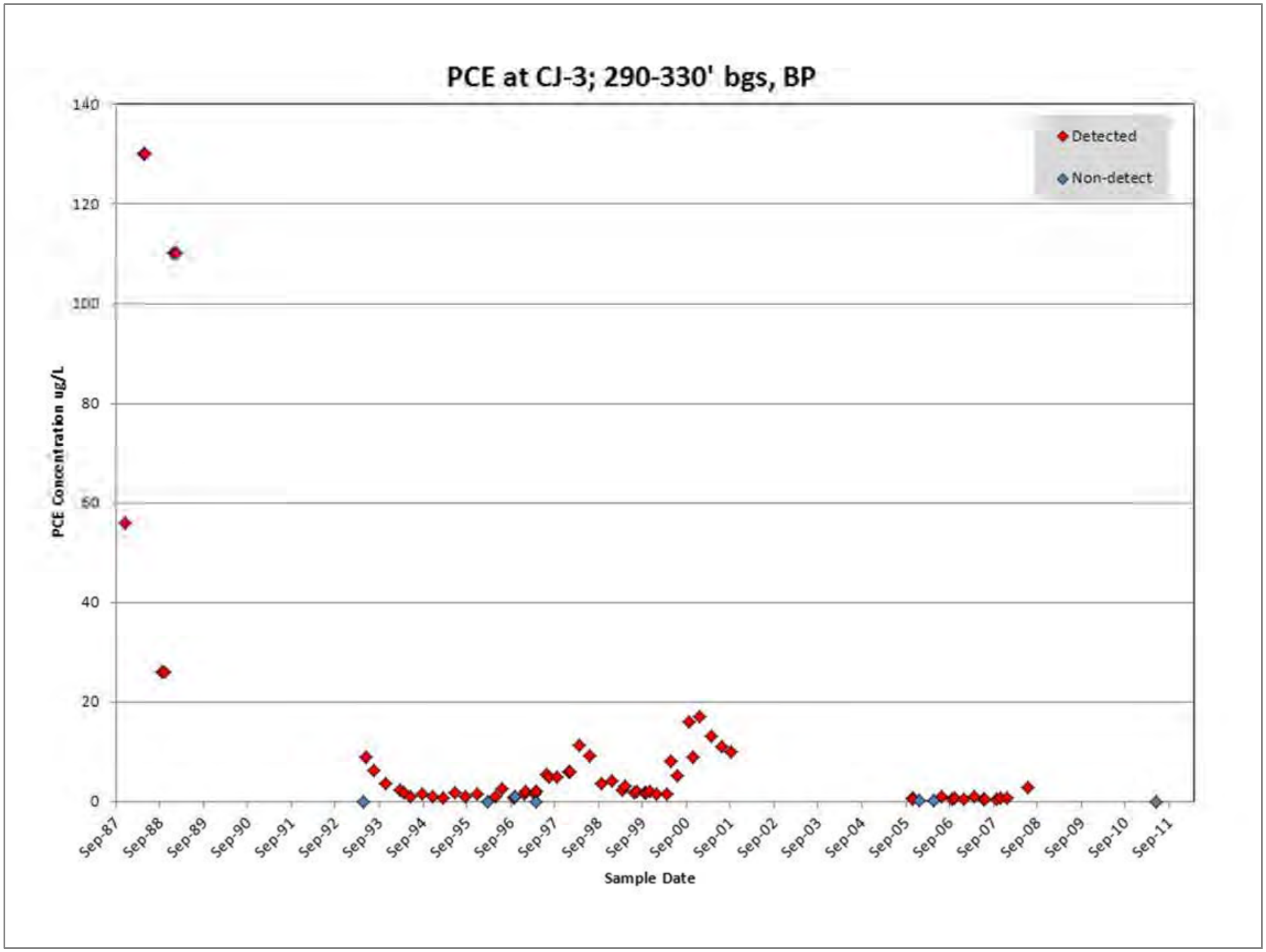


Figure A-2. Time series trend plot of PCE at monitoring well CJ-3. Sample collected 290-330 ft below ground surface. Sample type is Redi-Flo 4.

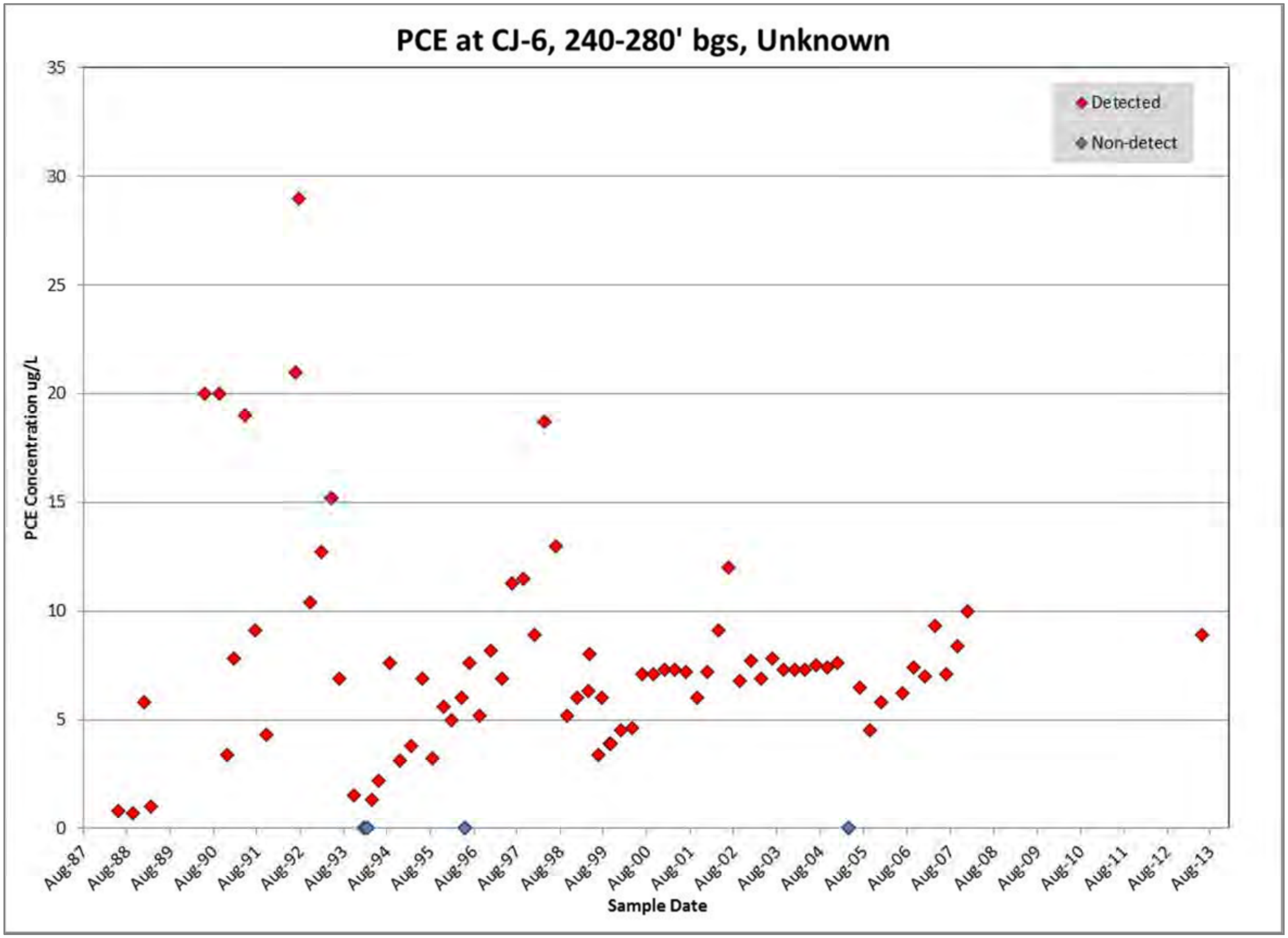


Figure A-3. Time series trend plot of PCE at monitoring well CJ-6. Sample collected 240-280 ft below ground surface. Sample type is Redi-Flo 2.

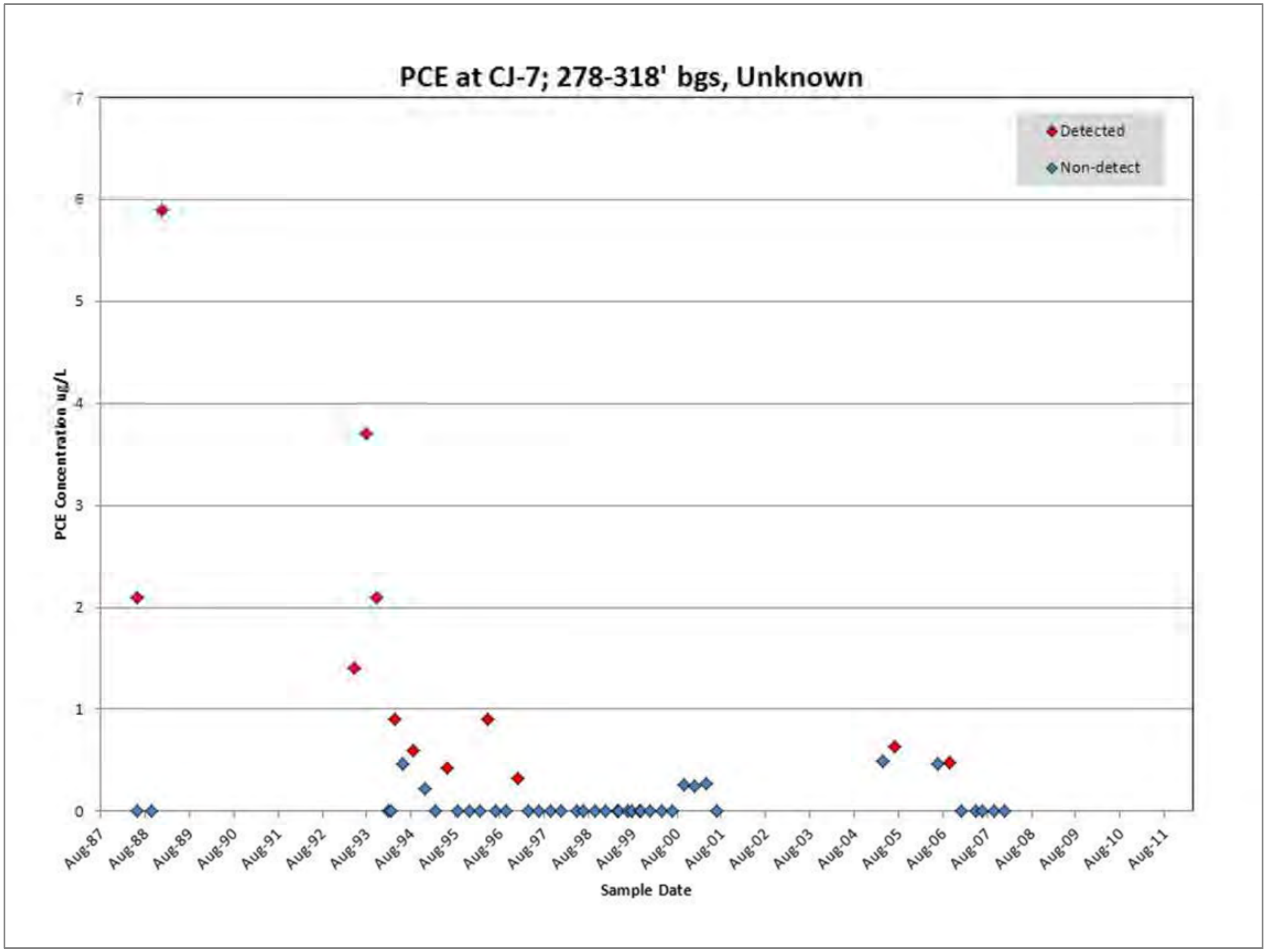


Figure A-4. Time series trend plot of PCE at monitoring well CJ-7. Sample collected 278-318 ft below ground surface. Sample type is Redi-Flo 4.

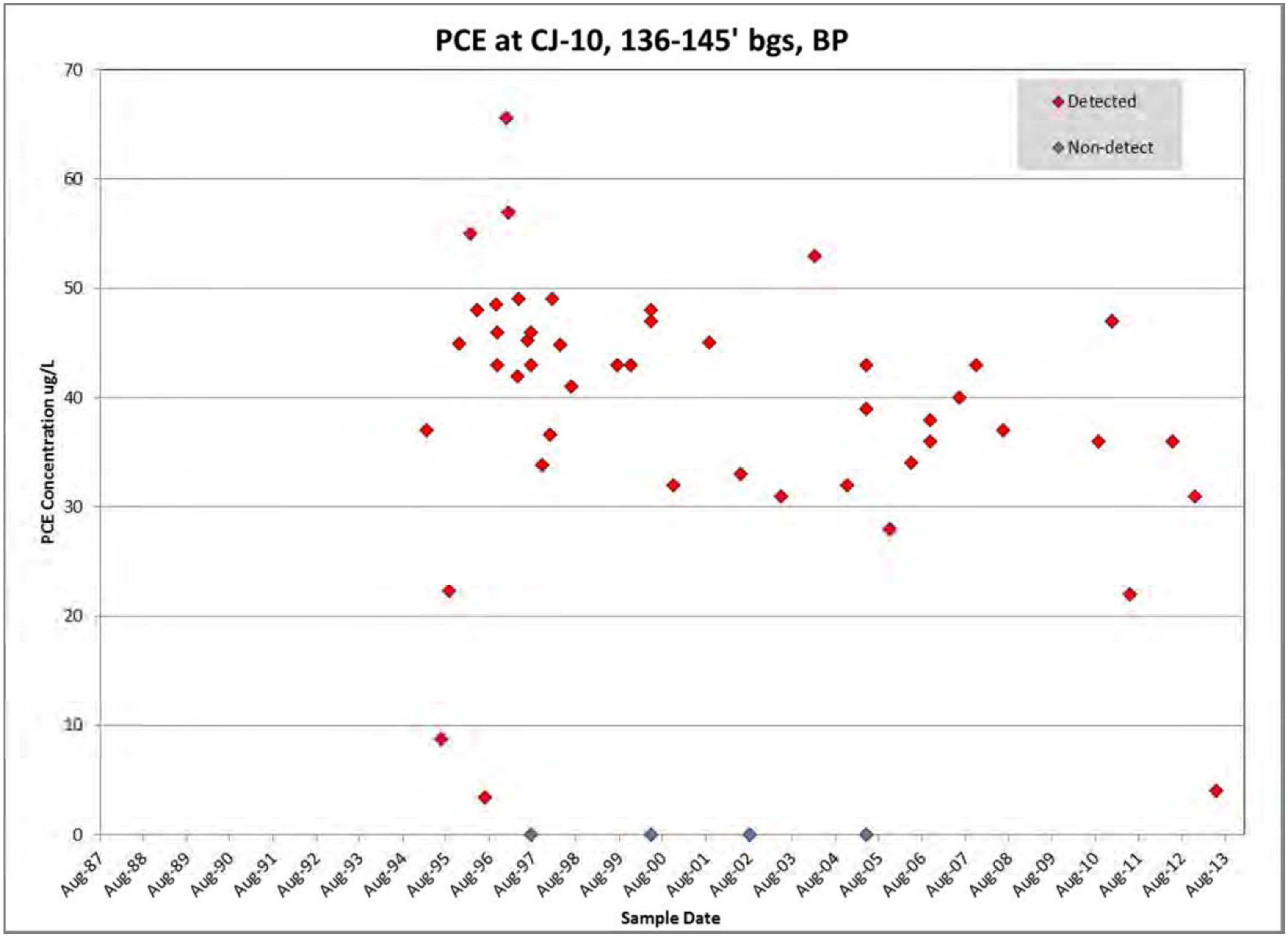


Figure A-5. Time series trend plot of PCE at monitoring well CJ-10. Sample collected 136-145 ft below ground surface. Sample type is bladder pump.

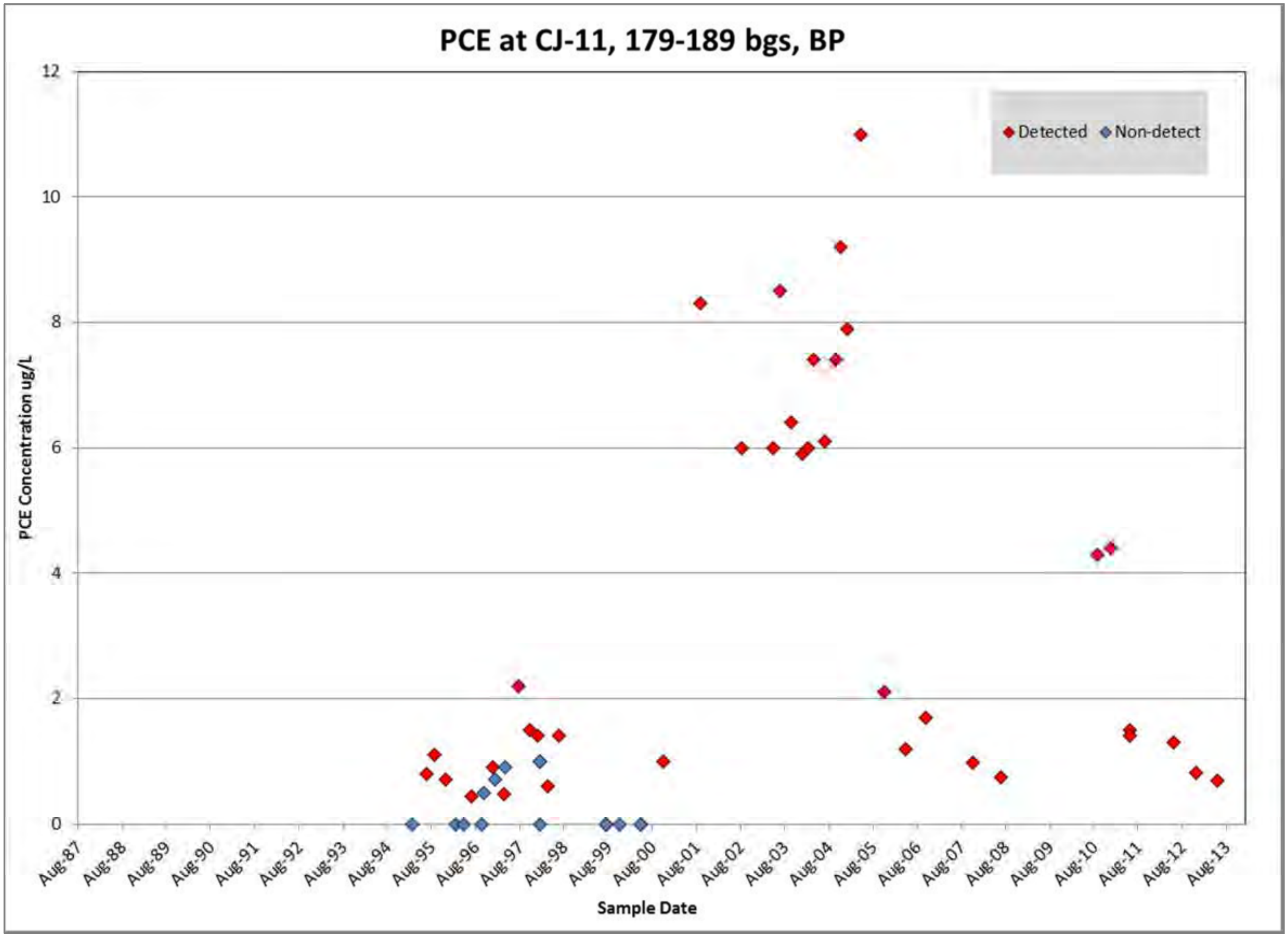


Figure A-6. Time series trend plot of PCE at monitoring well CJ-11. Sample collected 179-189 ft below ground surface. Sample type is bladder pump.

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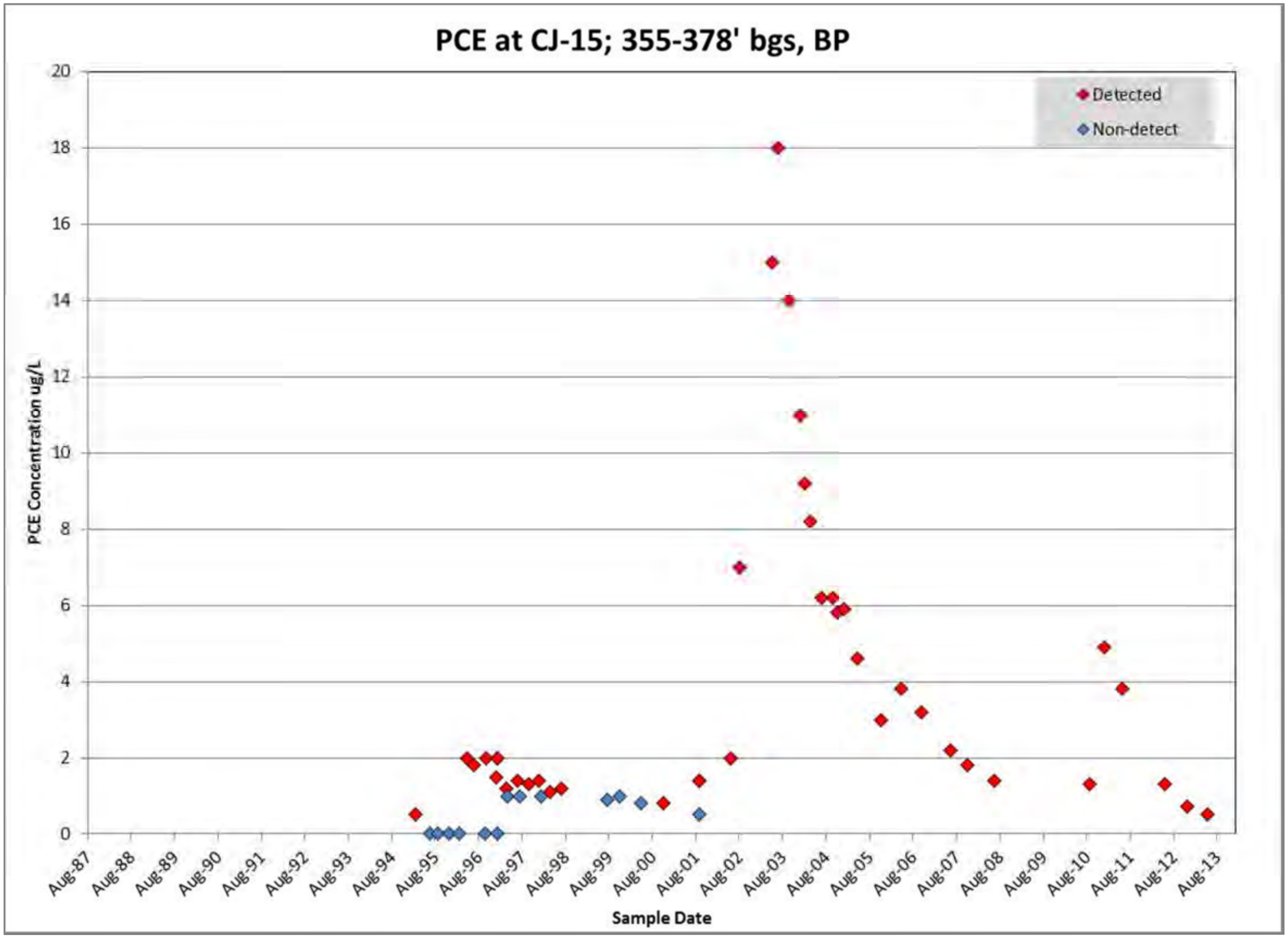

Figure A-7. Time series trend plot of PCE at monitoring well CJ-15. Sample collected 355-378 ft below ground surface. Sample type is Redi-Flo 4.

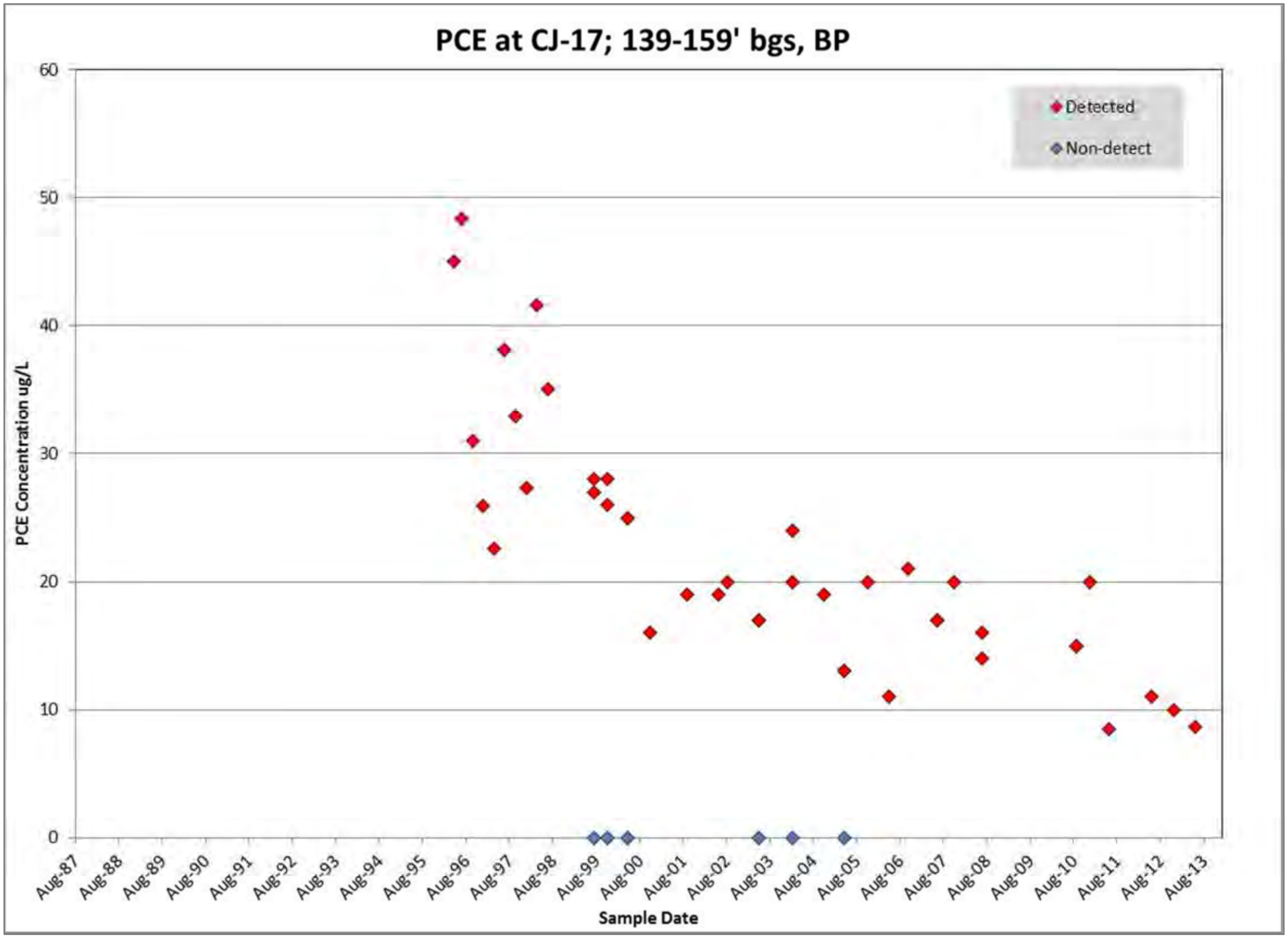

Figure A-8. Time series trend plot of PCE at monitoring well CJ-17. Sample collected 139-159 ft below ground surface. Sample type is Redi-Flo 2.

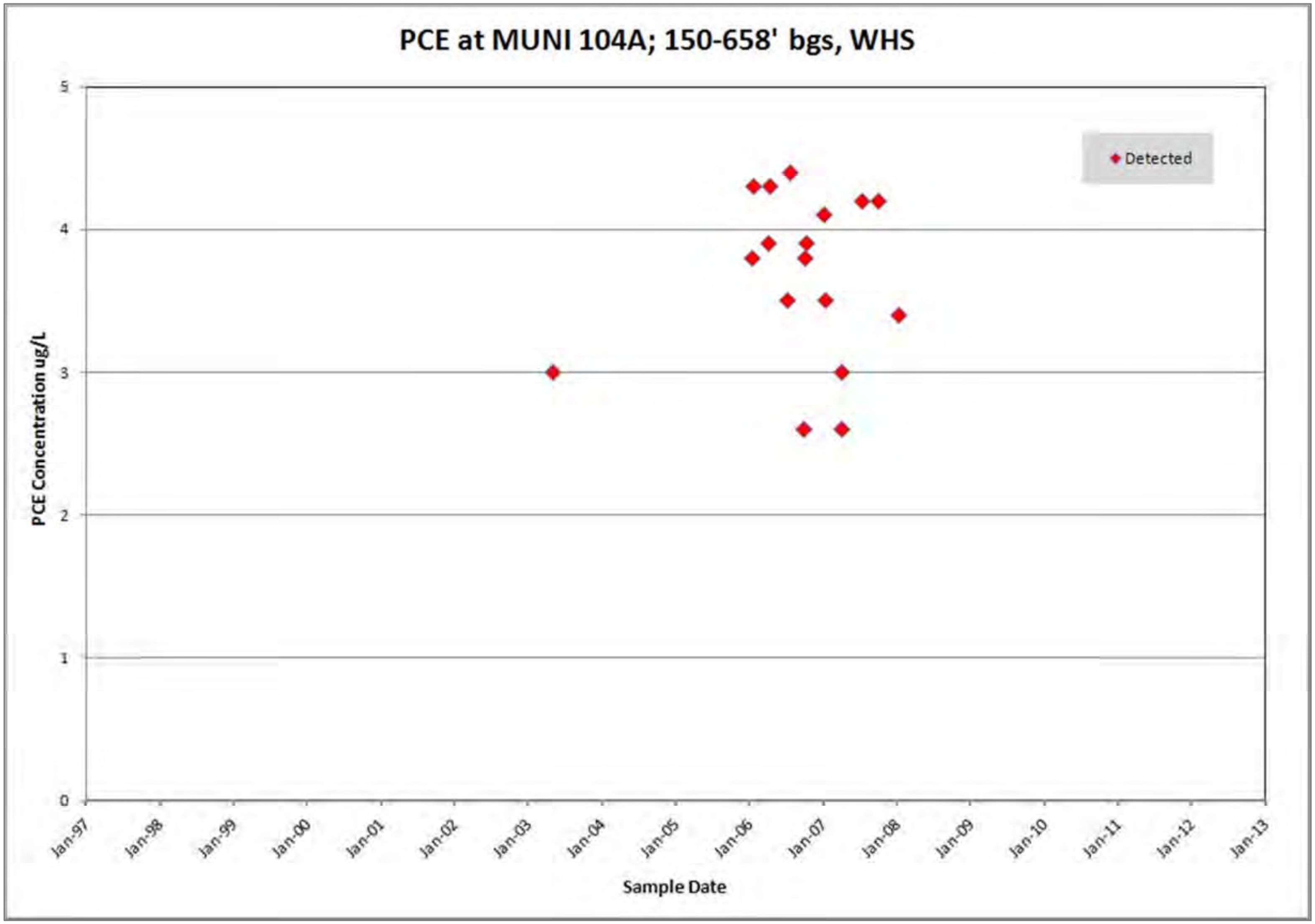

Figure A-9. Time series trend plot of PCE at well MUNI-104A. Sample collected 150-658 ft below ground surface. Sample type is well head spigot.

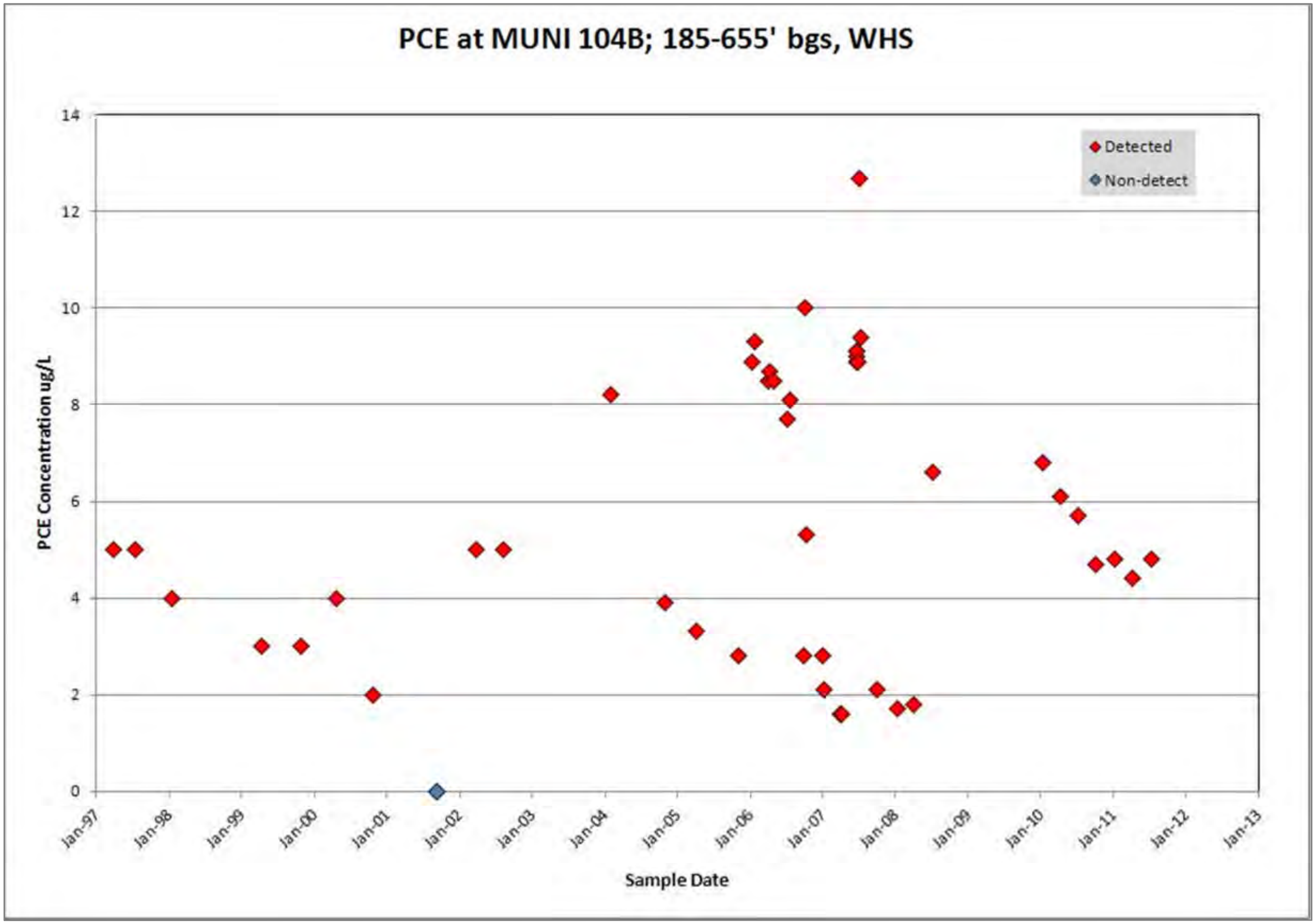

Figure A-10. Time series trend plot of PCE at well MUNI-104B. Sample collected 185-655 ft below ground surface. Sample type is well head spigot.

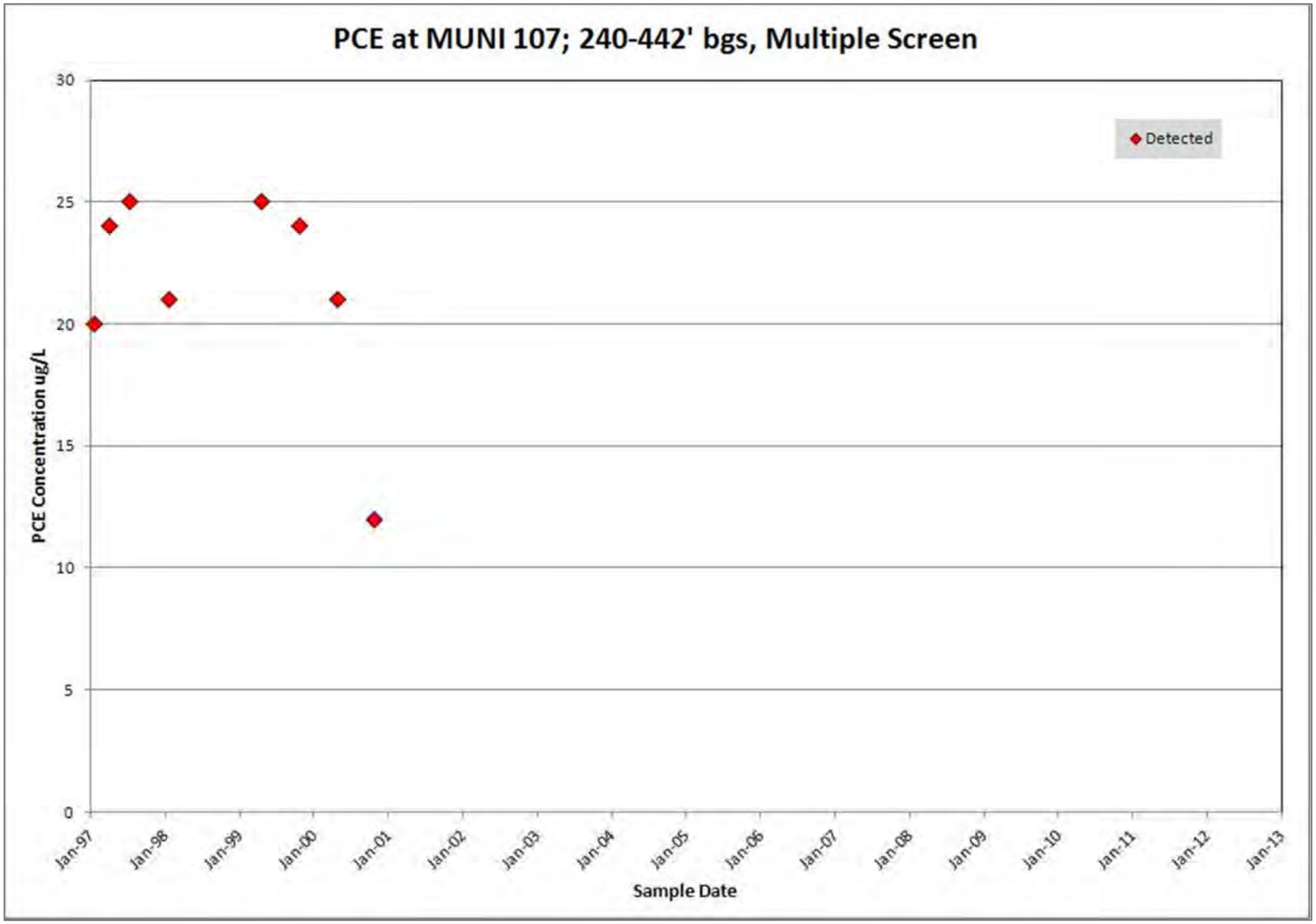

Figure A-11. Time series trend plot of PCE at monitoring well MUNI-107. Sample collected 240-442 ft below ground surface. Sample type is multiple screen.

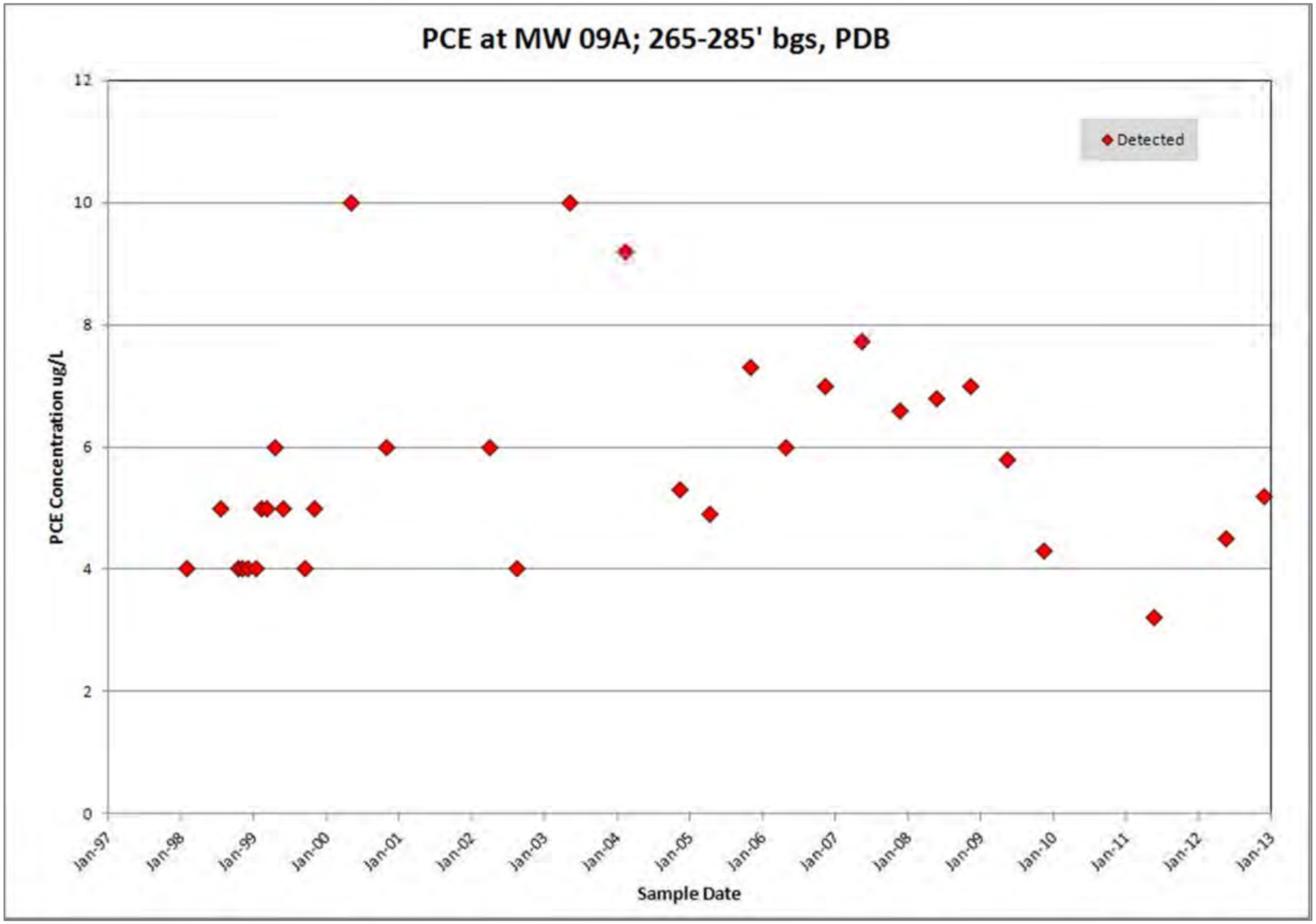

Figure A-12. Time series trend plot of PCE at monitoring well MW 09A. Sample collected 275 ft below ground surface. Sample type is passive diffusion bag.

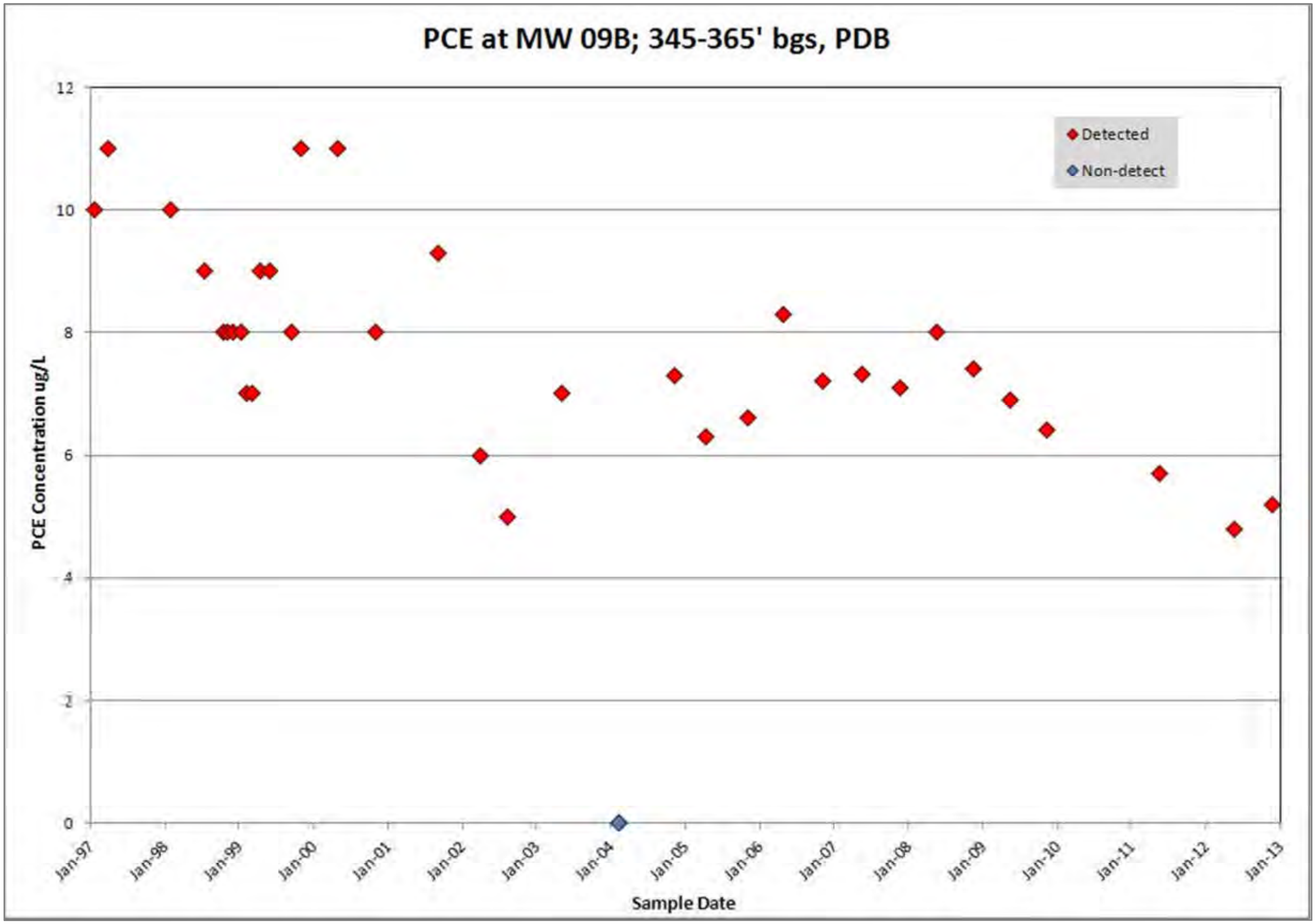

Figure A-13. Time series trend plot of PCE at monitoring well MW 09B. Sample collected 355 ft below ground surface. Sample type is passive diffusion bag.

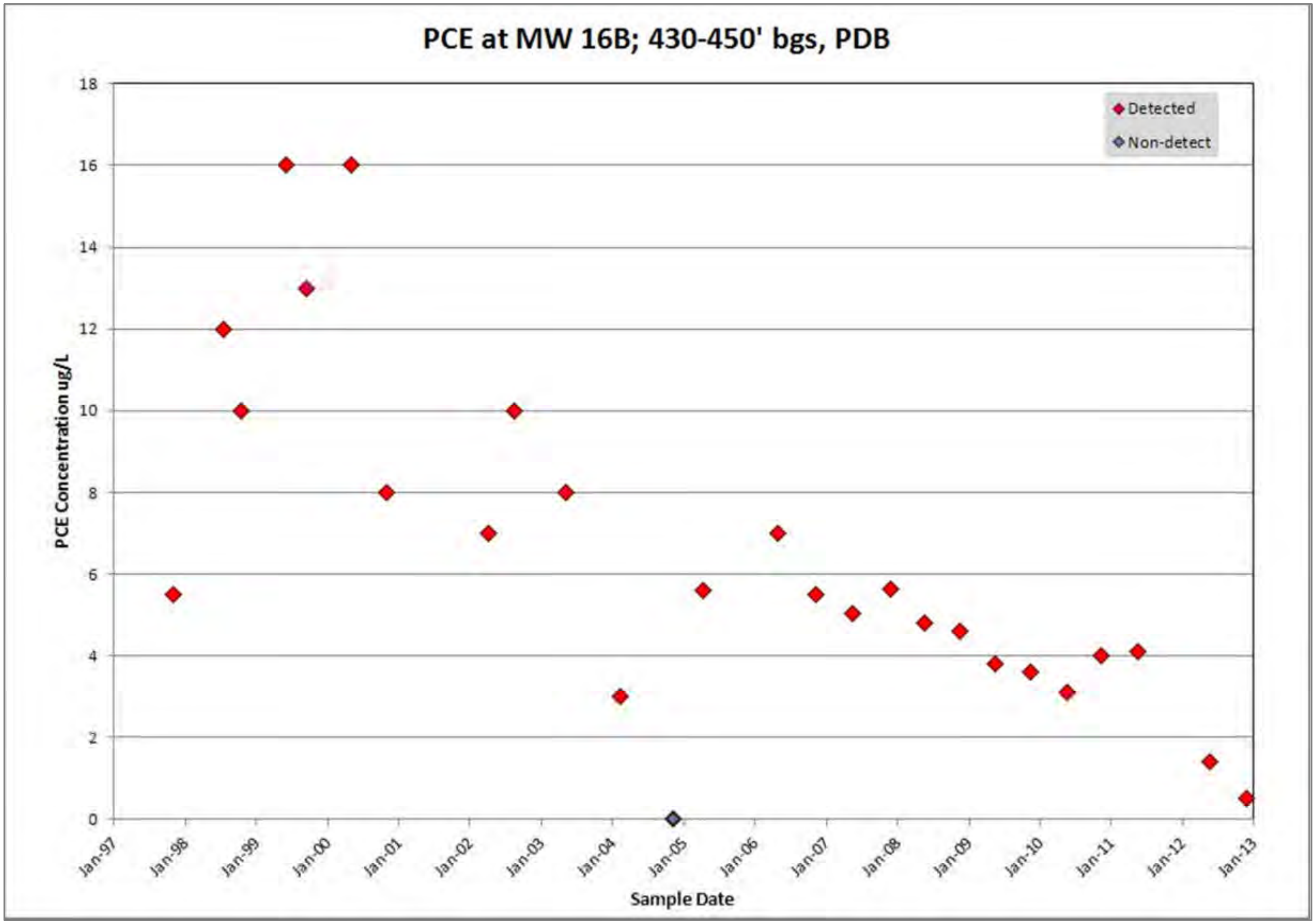

Figure A-14. Time series trend plot of PCE at monitoring well MW 16B. Sample collected 440 ft below ground surface. Sample type is passive diffusion bag.

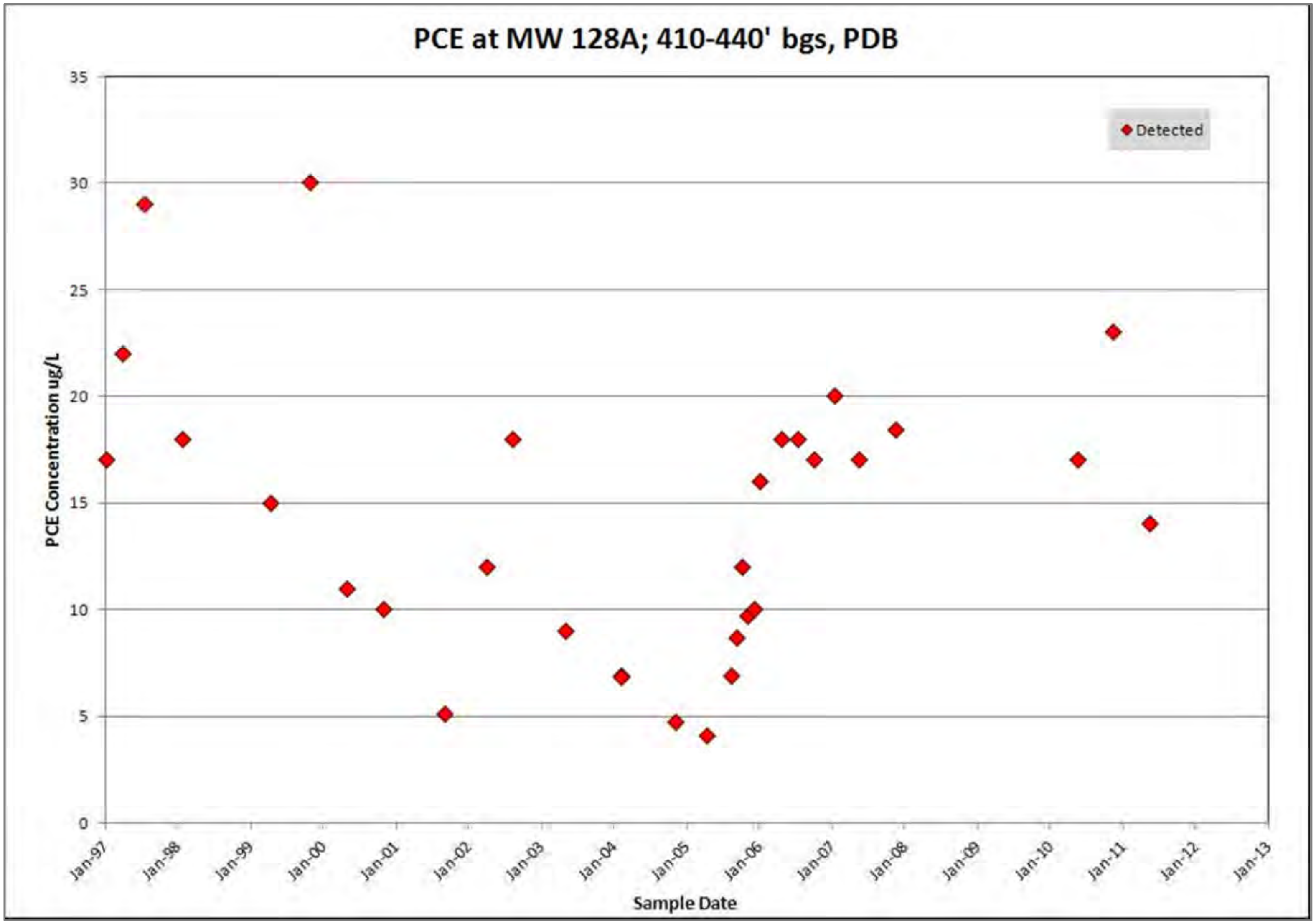

Figure A-15. Time series trend plot of PCE at monitoring well MW 128A. Sample collected 425 ft below ground surface. Sample type is passive diffusion bag.

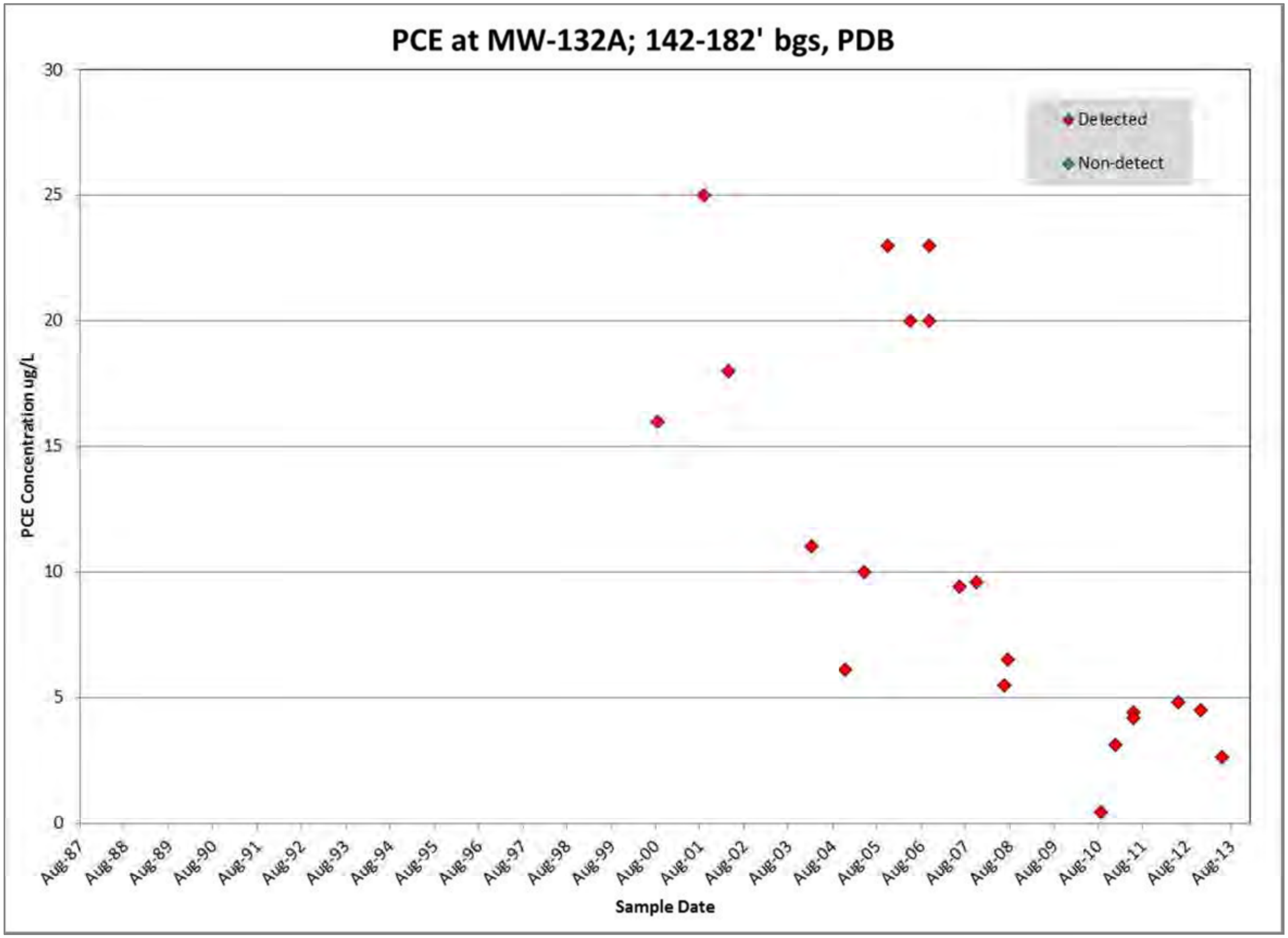

Figure A-16. Time series trend plot of PCE at monitoring well MW-132A. Sample collected 181 ft below ground surface. Sample type is passive diffusion bag.

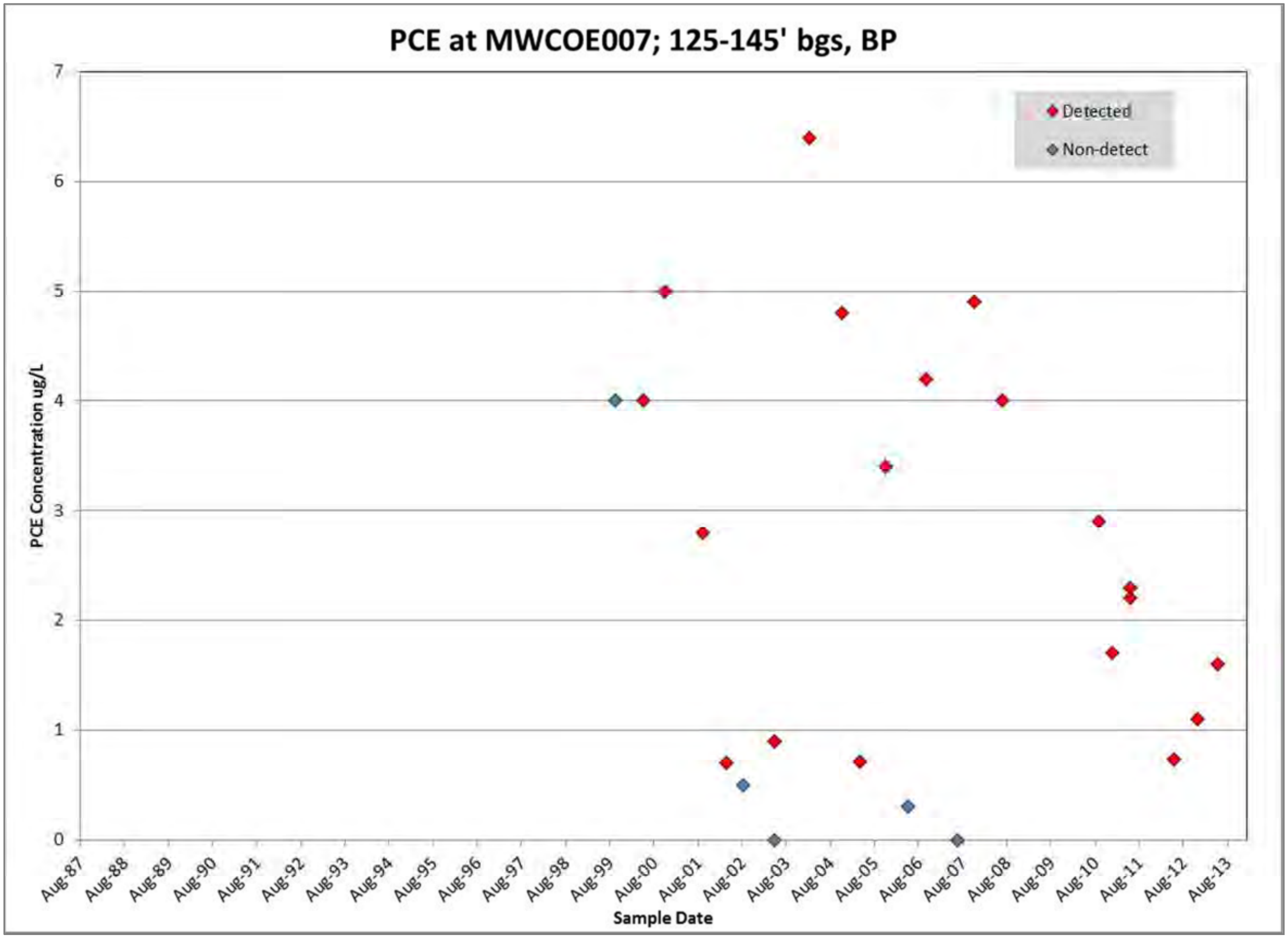

Figure A-17. Time series trend plot of PCE at monitoring well MECOE007. Sample collected 135 ft below ground surface. Sample type is passive diffusion bag.

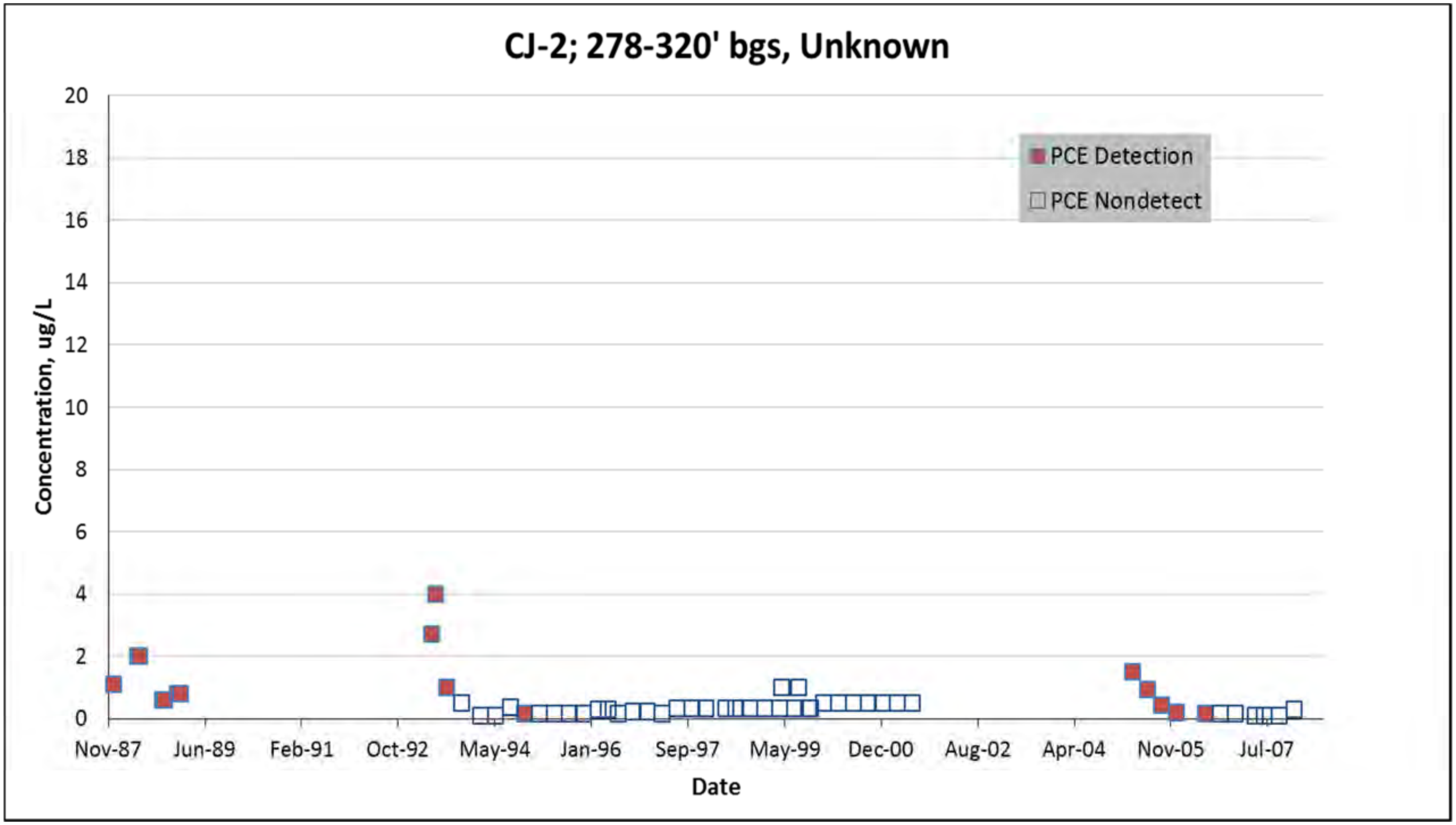

Figure A-18. Time series trend plot of PCE at monitoring well CJ-2. Sample collected 278-320 ft below ground surface. Sample type is Redi-Flo 4.

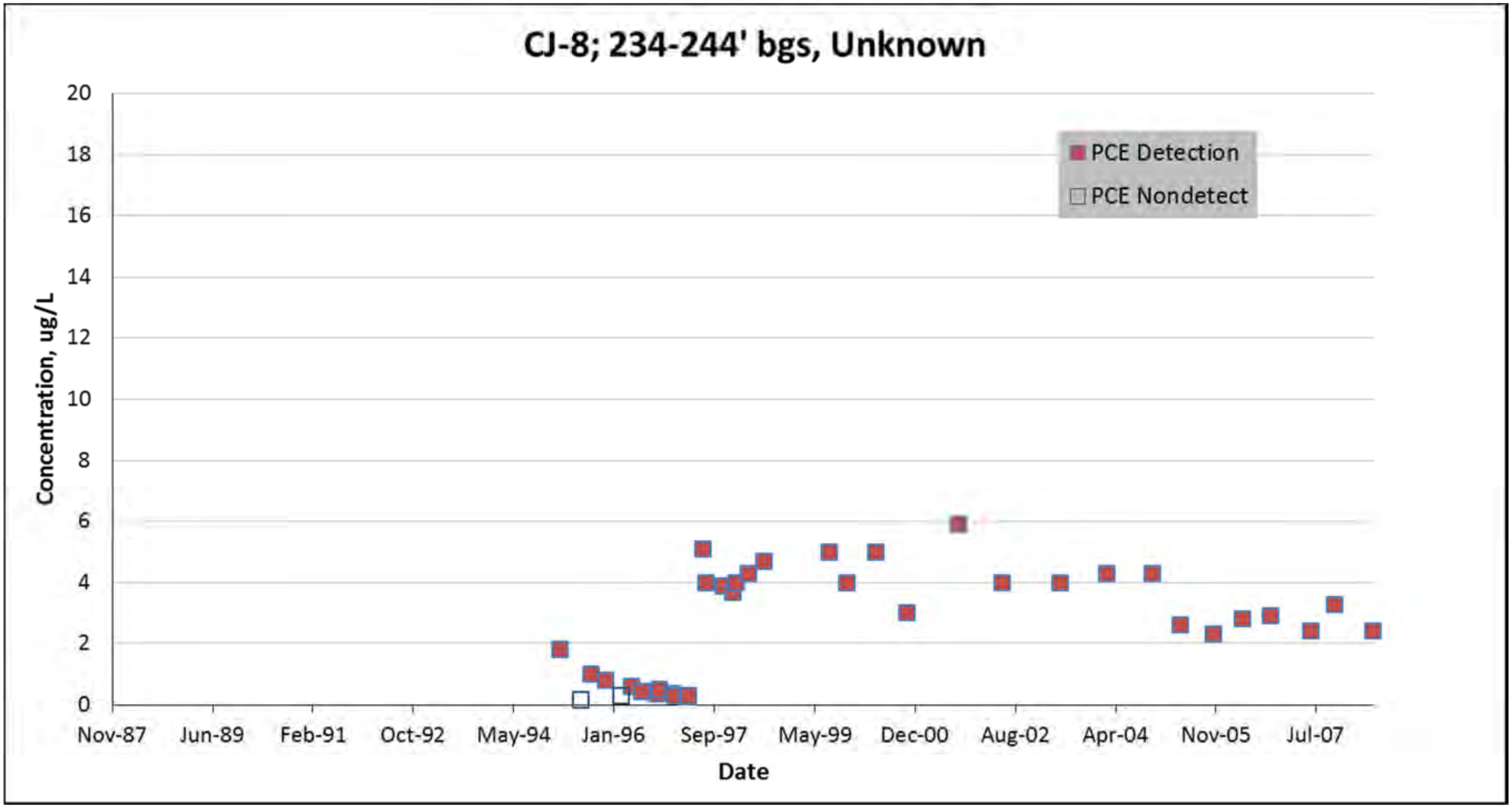

Figure A-19. Time series trend plot of PCE at monitoring well CJ-8. Sample collected 234-244 ft below ground surface. Sample type is bladder pump.

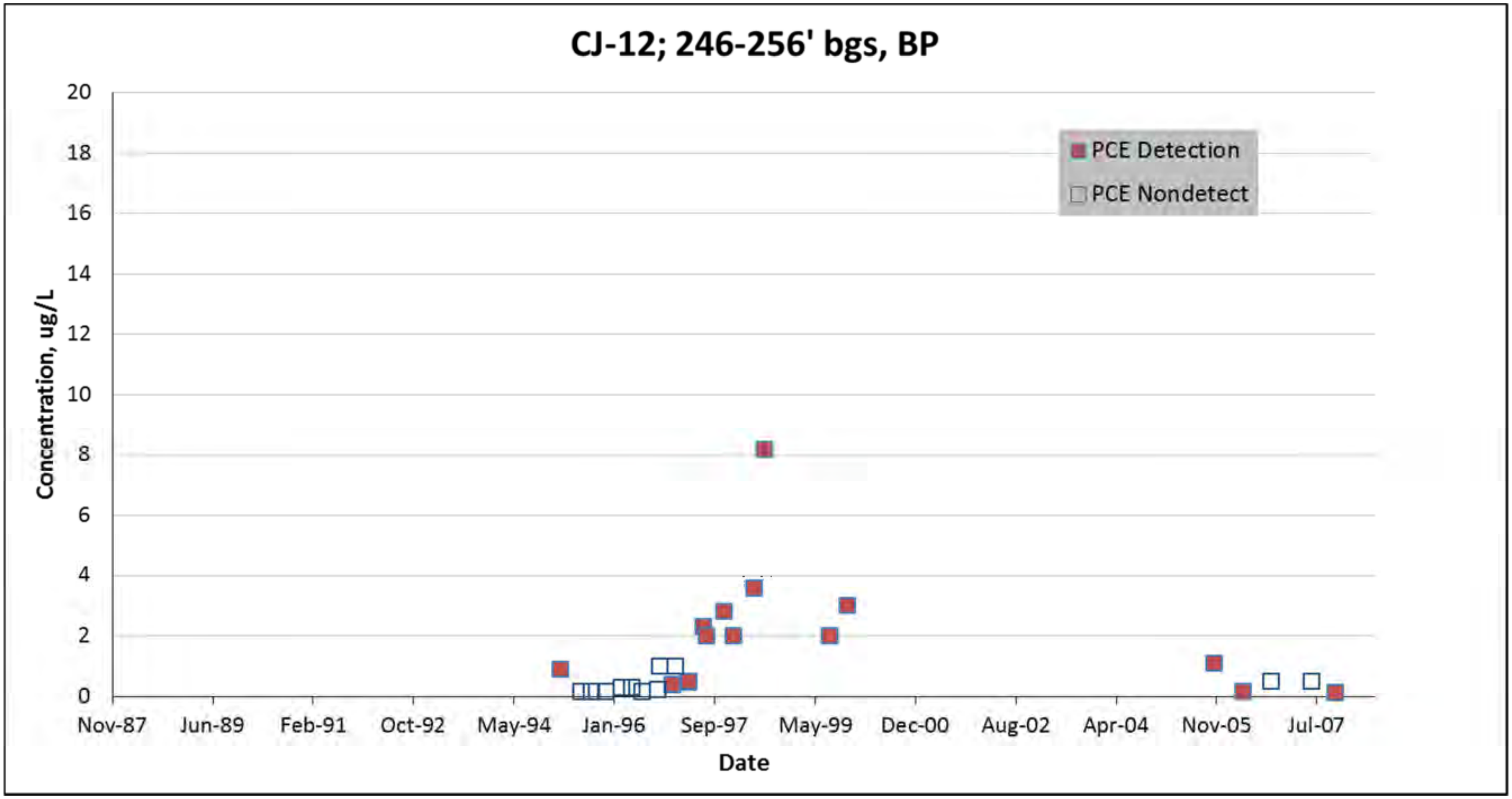

Figure A-20. Time series trend plot of PCE at monitoring well CJ-12. Sample collected 246-256 ft below ground surface. Sample type is bailer.

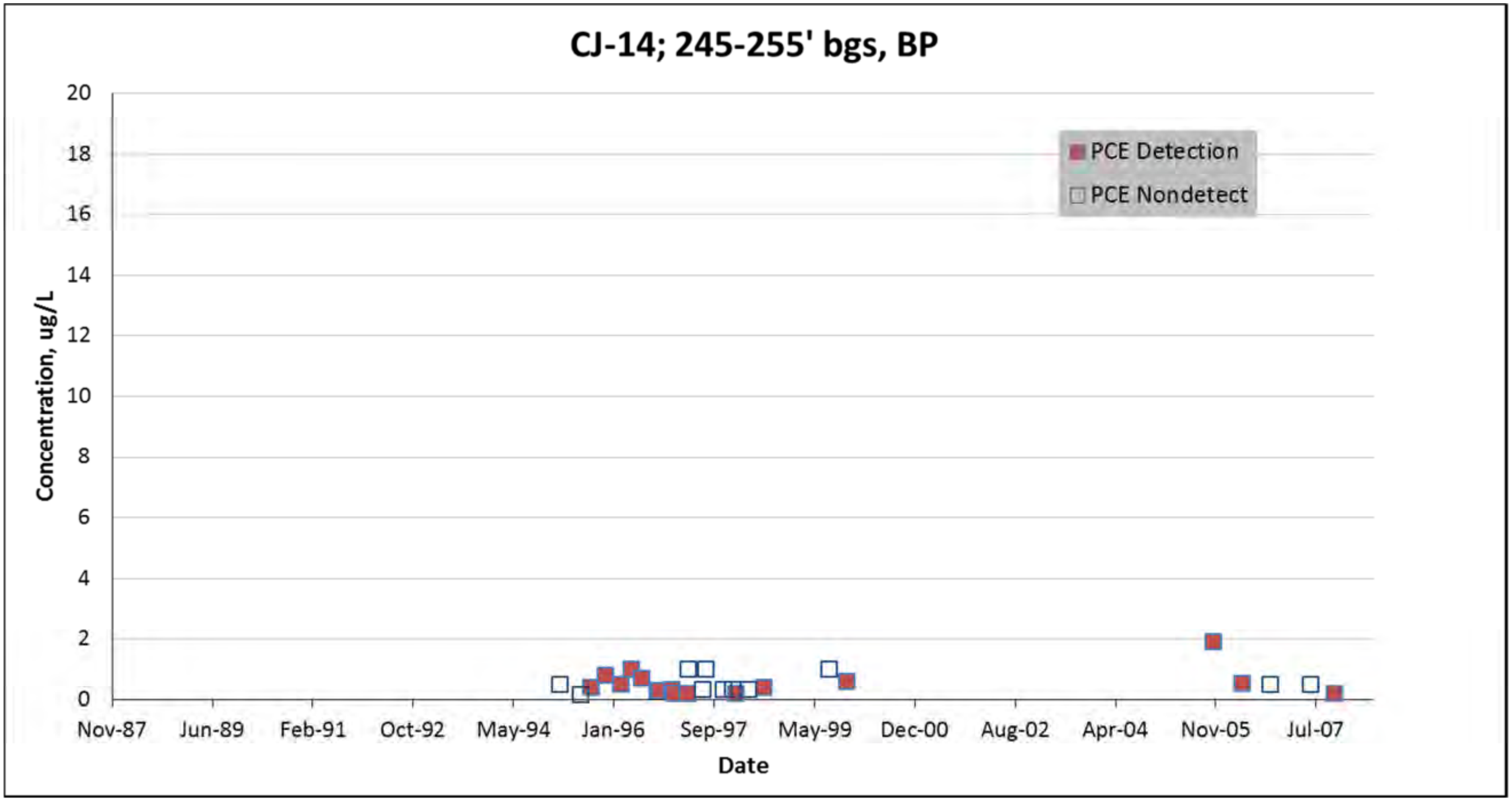

Figure A-21. Time series trend plot of PCE at monitoring well CJ-14. Sample collected 245-255 ft below ground surface. Sample type is bailer.

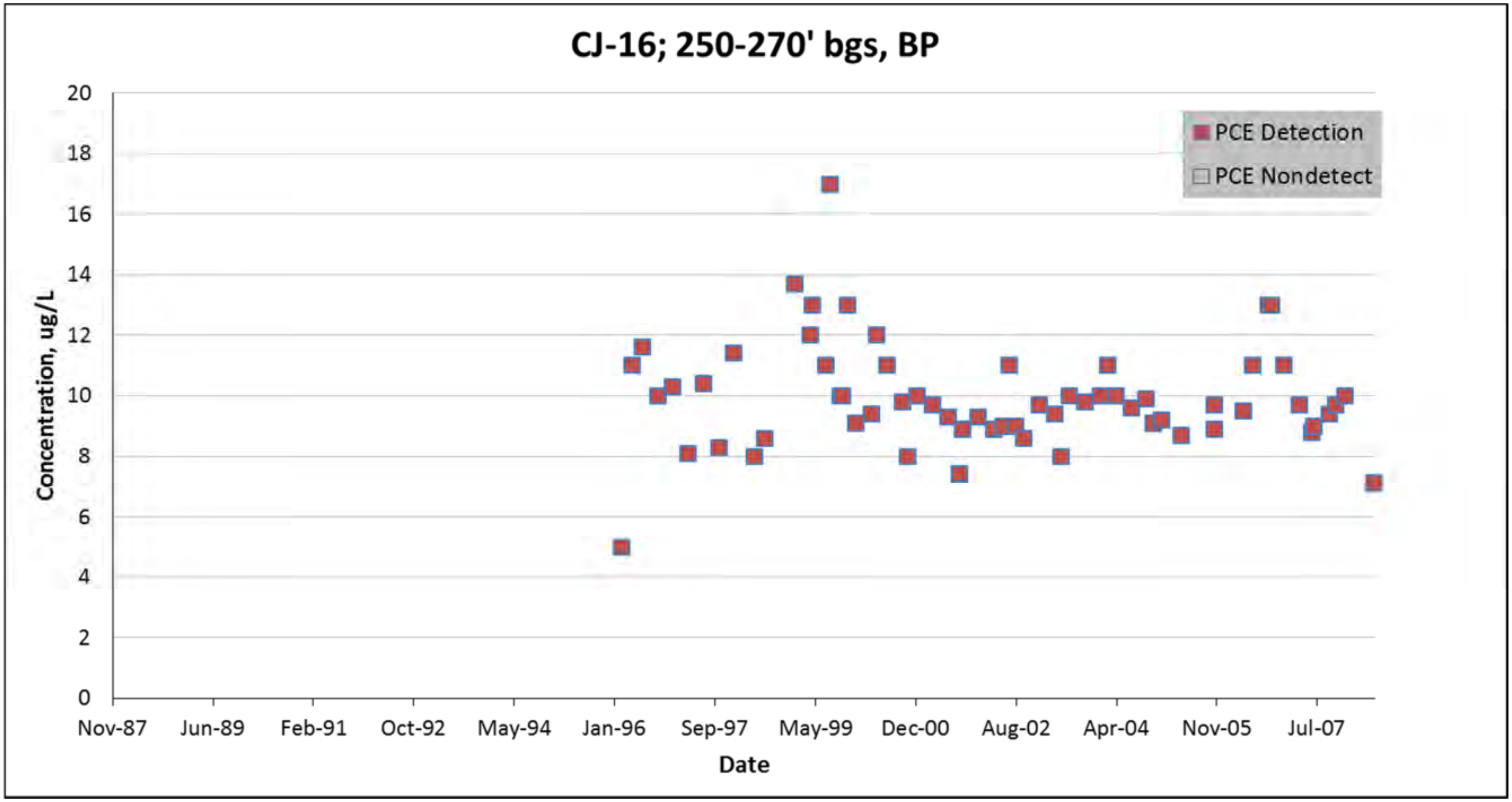

Figure A-22. Time series trend plot of PCE at monitoring well CJ-16. Sample collected 250-270 ft below ground surface. Sample type is Redi-Flo 2.

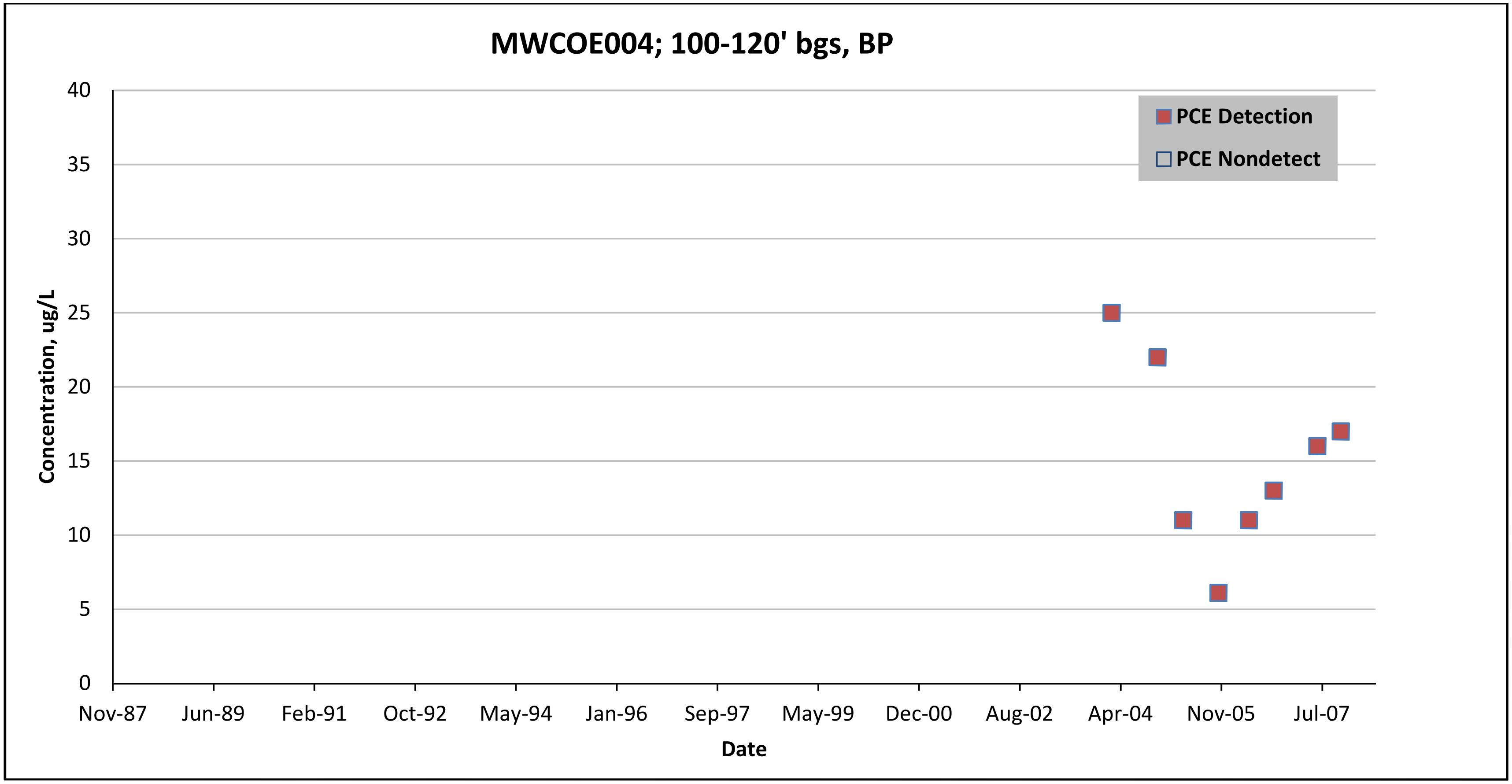

Figure A-23. Time series trend plot of PCE at monitoring well MWCOE004. Sample collected 110 ft below ground surface. Sample type is passive diffusion bag.

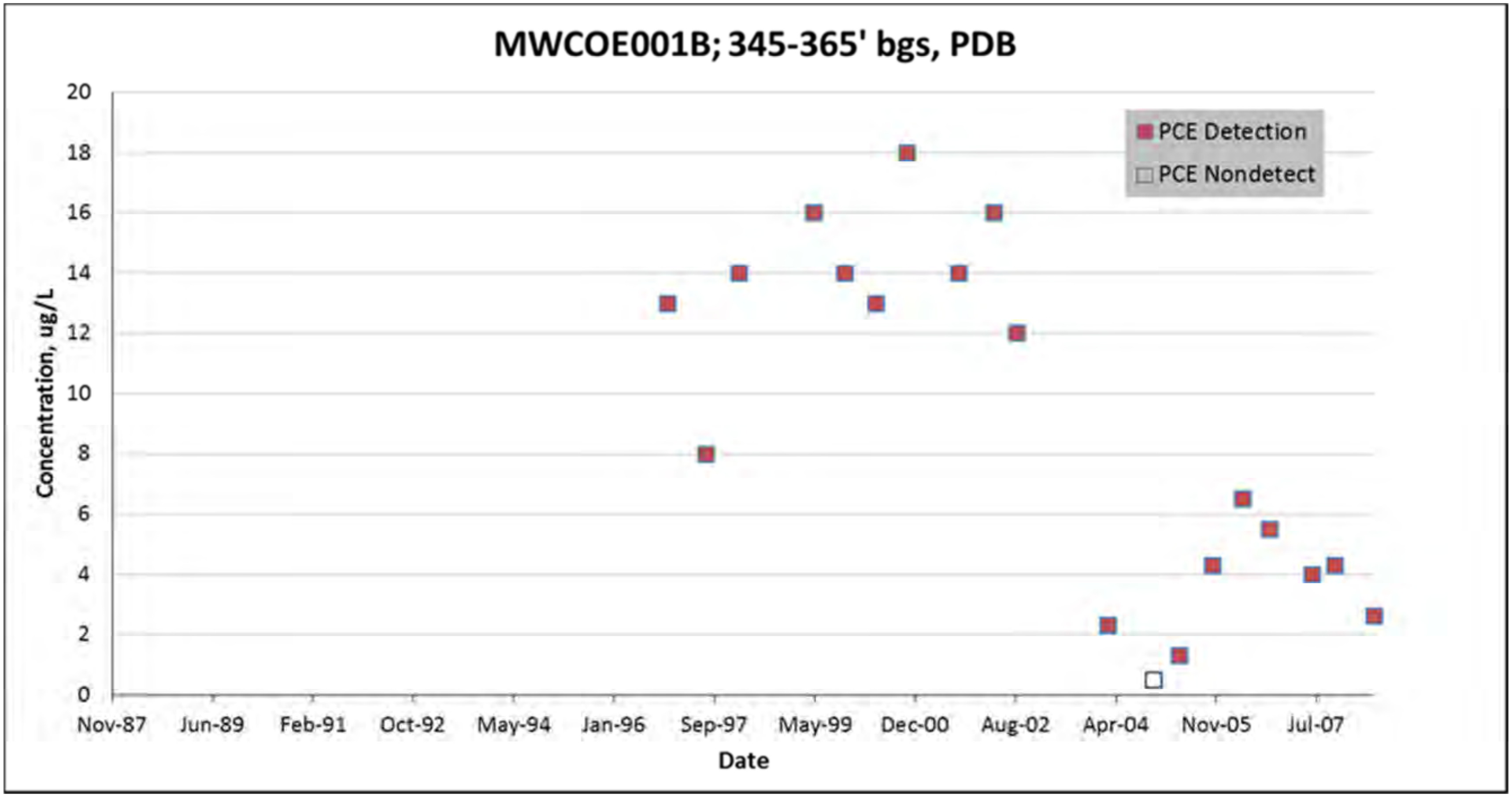

Figure A-24. Time series trend plot of PCE at monitoring well MWCOE001B. Sample collected 357 ft below ground surface. Sample type is passive diffusion bag.

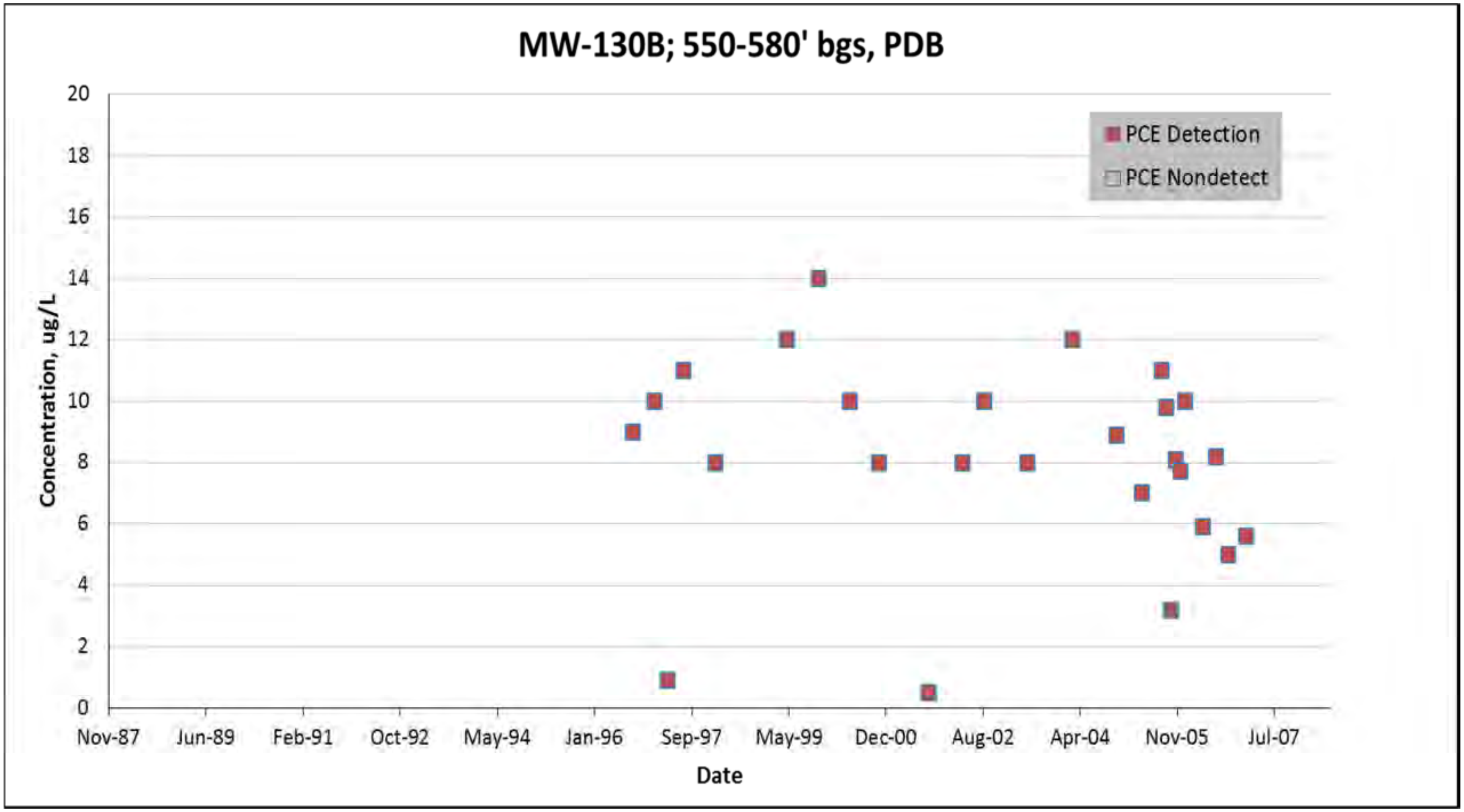

Figure A-25. Time series trend plot of PCE at monitoring well MW-130B. Sample collected 565 ft below ground surface. Sample type is passive diffusion bag.

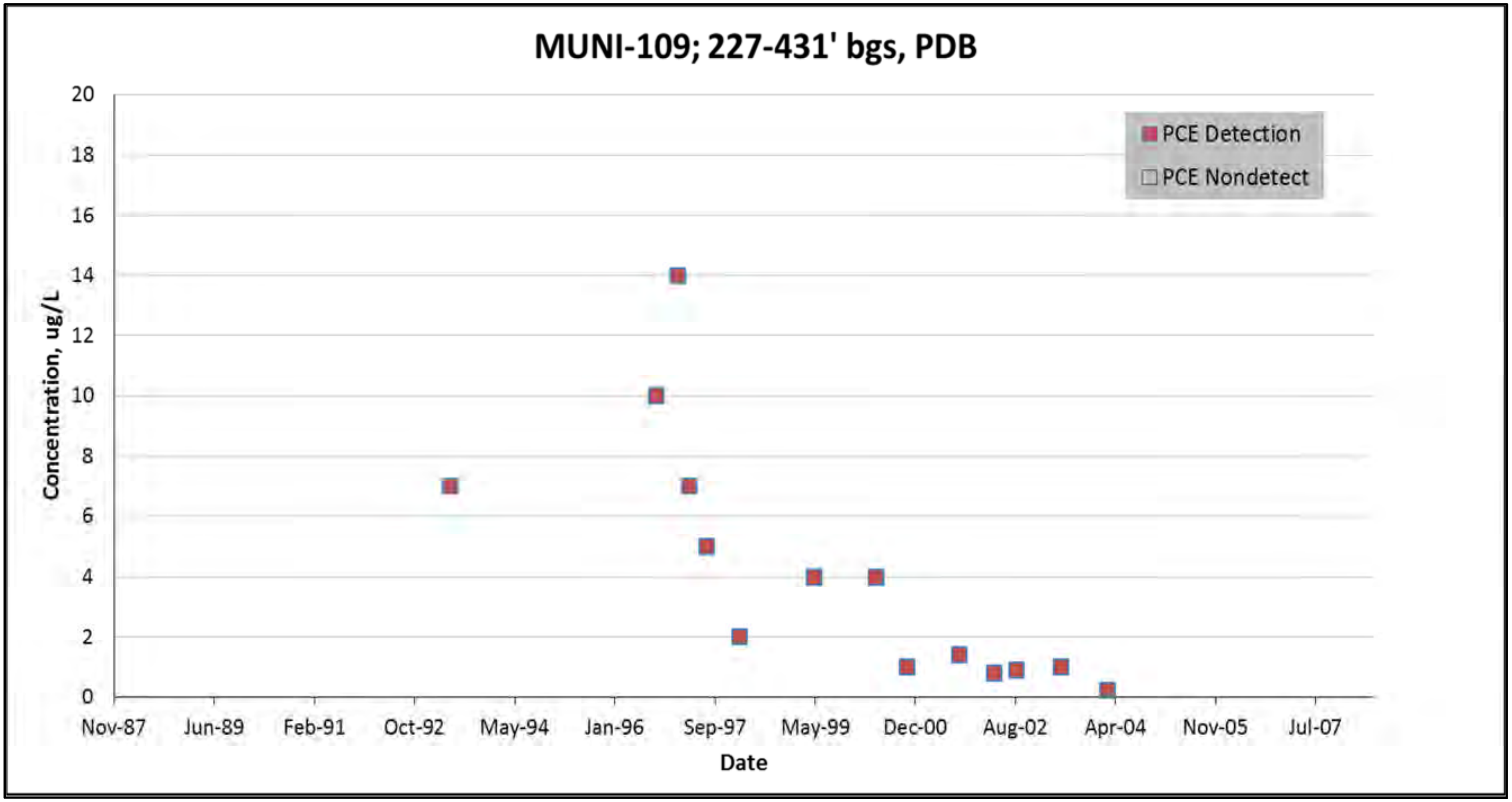

Figure A-26. Time series trend plot of PCE at monitoring well MUNI-109. Sample collected 329 ft below ground surface. Sample type is passive diffusion bag.

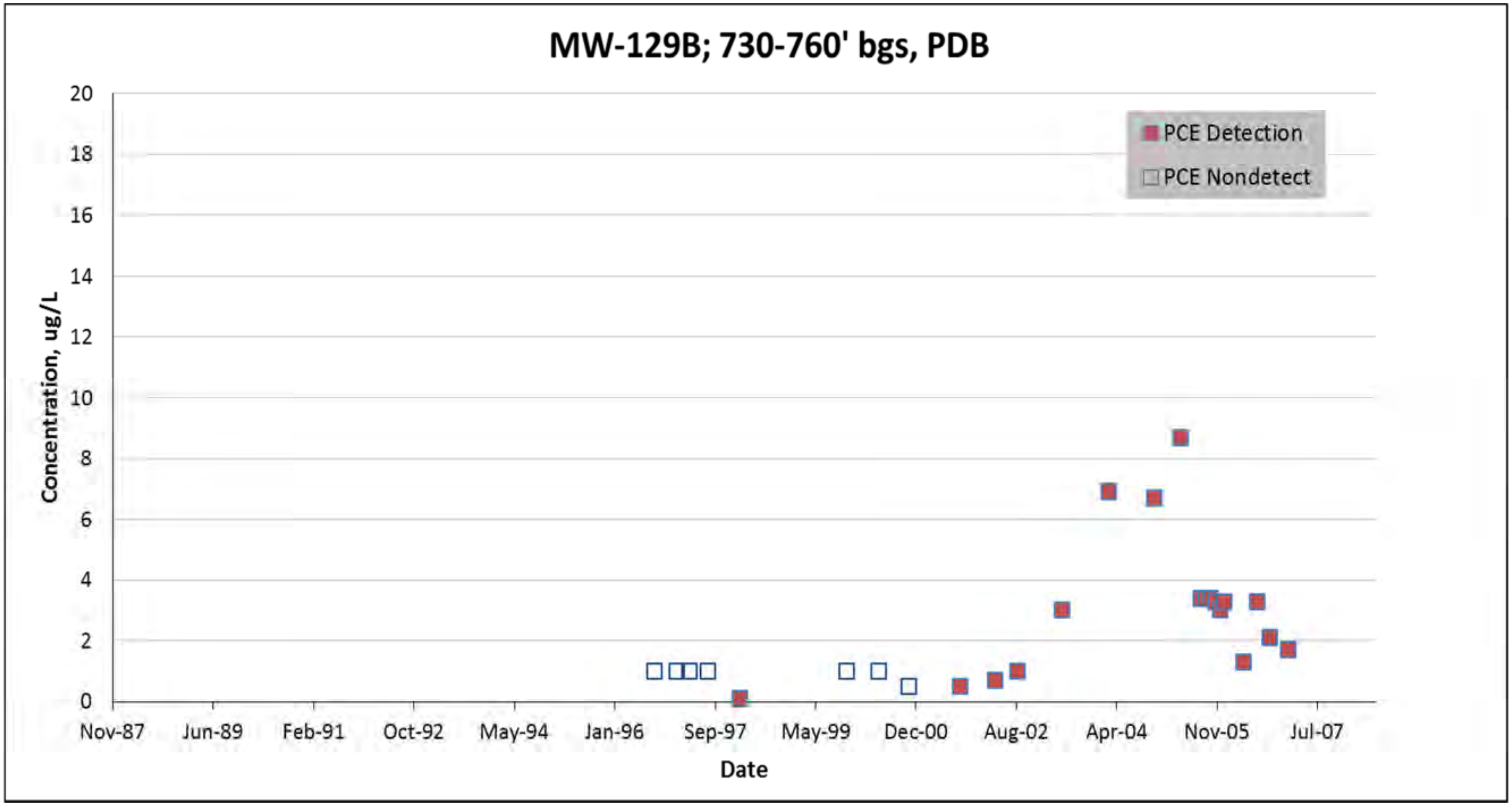

Figure A-27. Time series trend plot of PCE at monitoring well MW-129B. Sample collected 745 ft below ground surface. Sample type is passive diffusion bag.

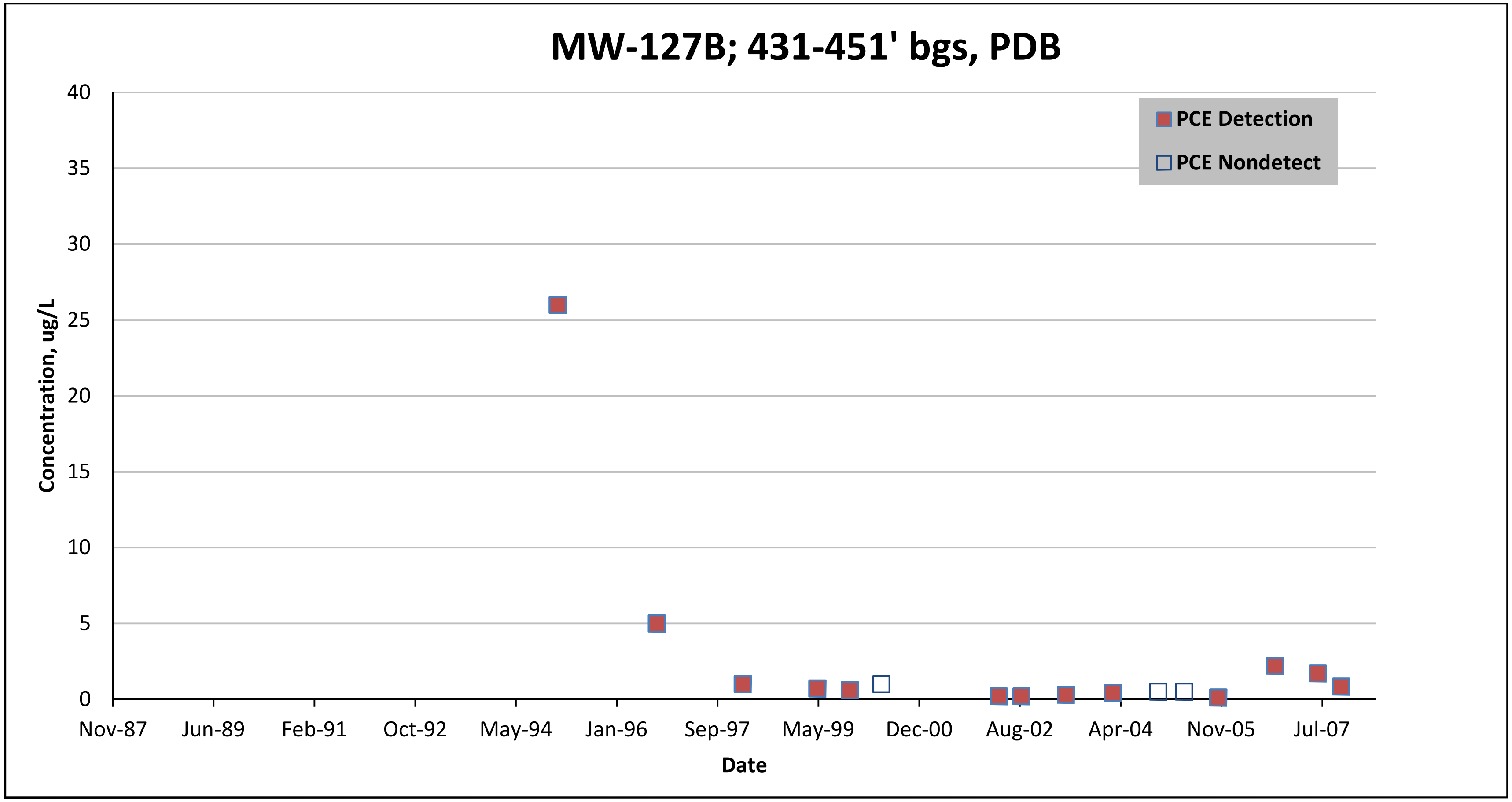

Figure A-28. Time series trend plot of PCE at monitoring well MW-127B. Sample collected 441 ft below ground surface. Sample type is passive diffusion bag.

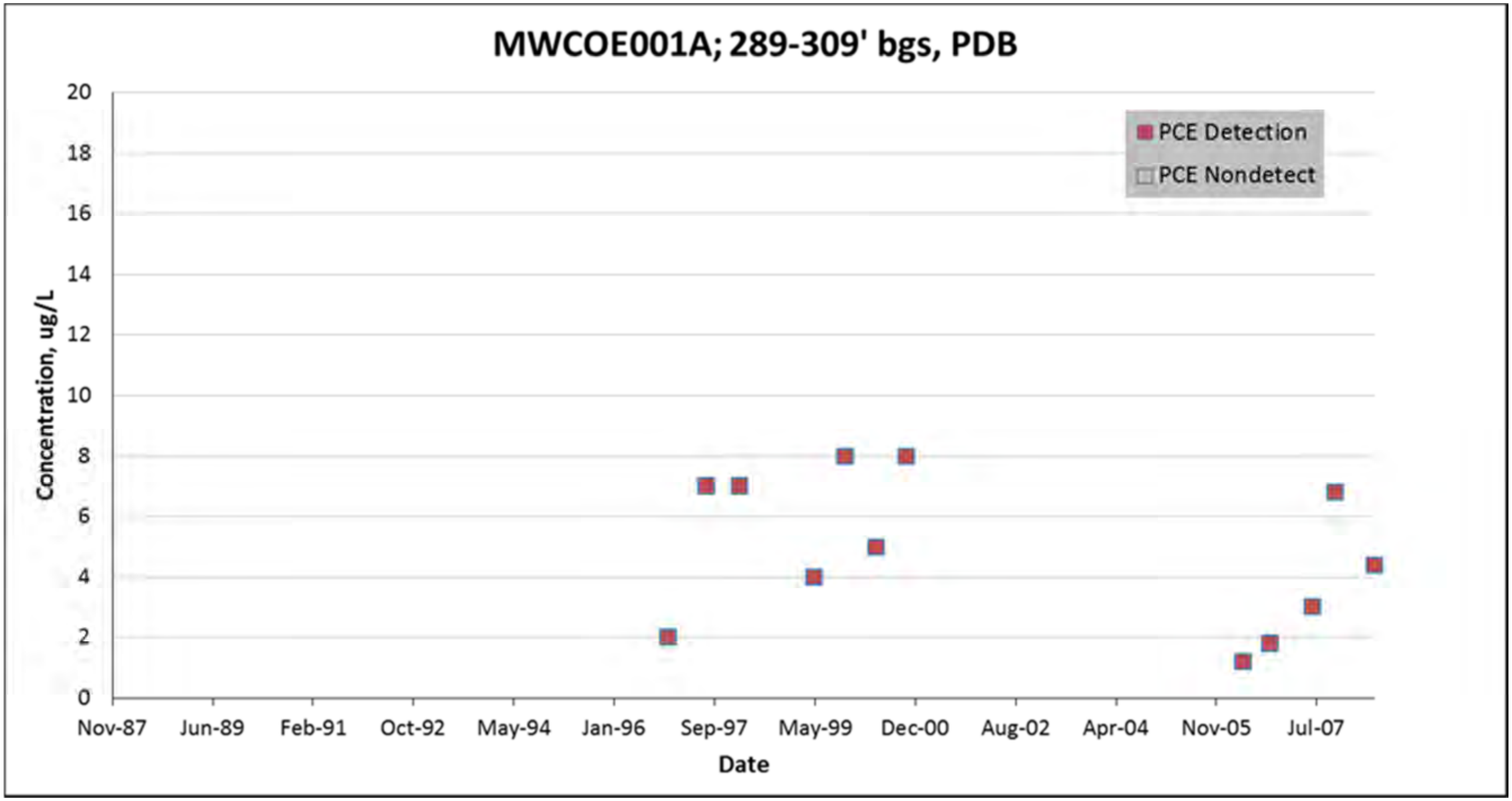

Figure A-29. Time series trend plot of PCE at monitoring well MWCOE001A. Sample collected 299 ft below ground surface. Sample type is passive diffusion bag.

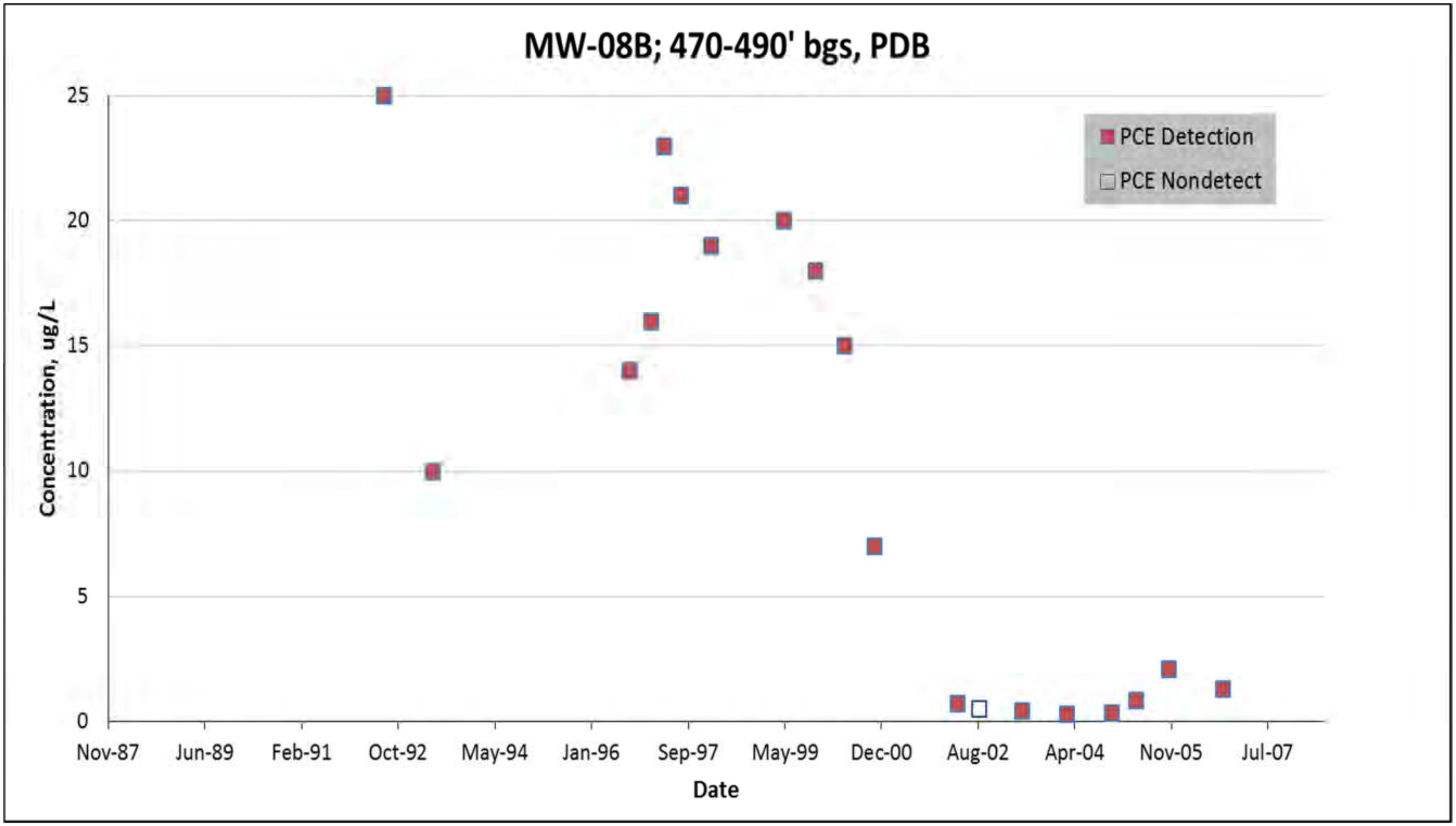

Figure A-30. Time series trend plot of PCE at monitoring well MW-08B. Sample collected 480 ft below ground surface. Sample type is passive diffusion bag.

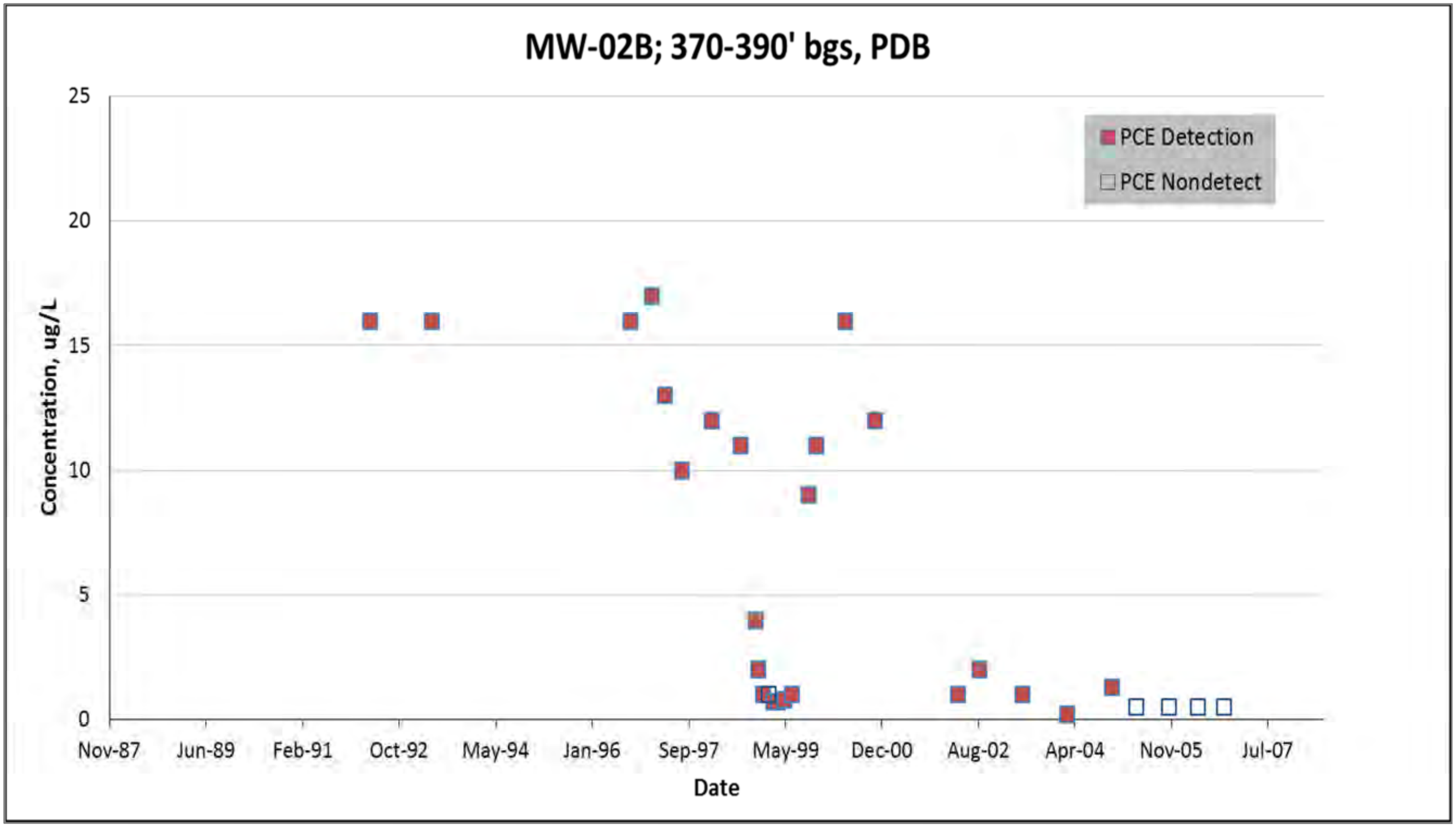

Figure A-31. Time series trend plot of PCE at monitoring well MW-02B. Sample collected 380 ft below ground surface. Sample type is passive diffusion bag.

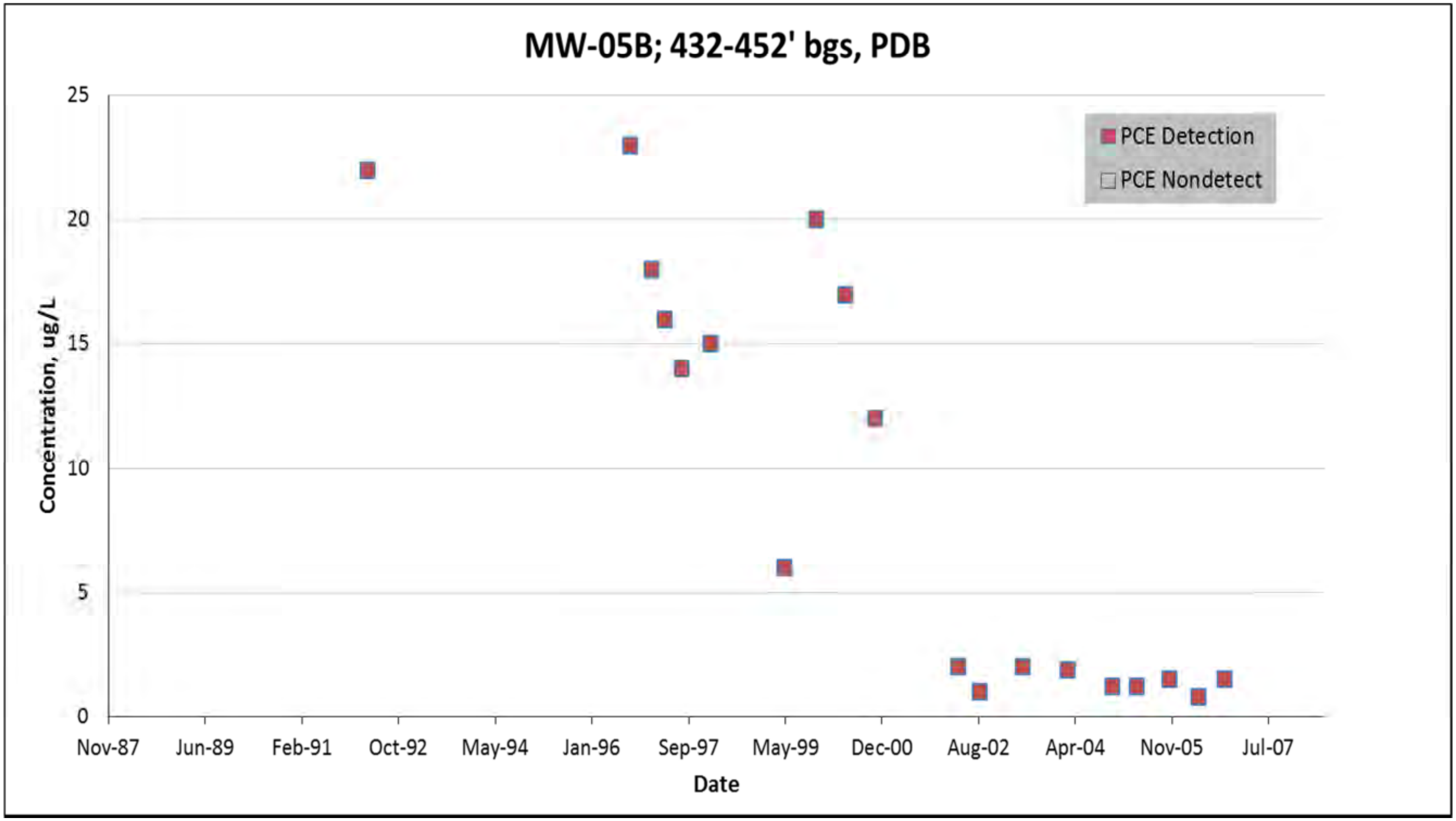

Figure A-32. Time series trend plot of PCE at monitoring well MW-05B. Sample collected 442 ft below ground surface. Sample type is passive diffusion bag.

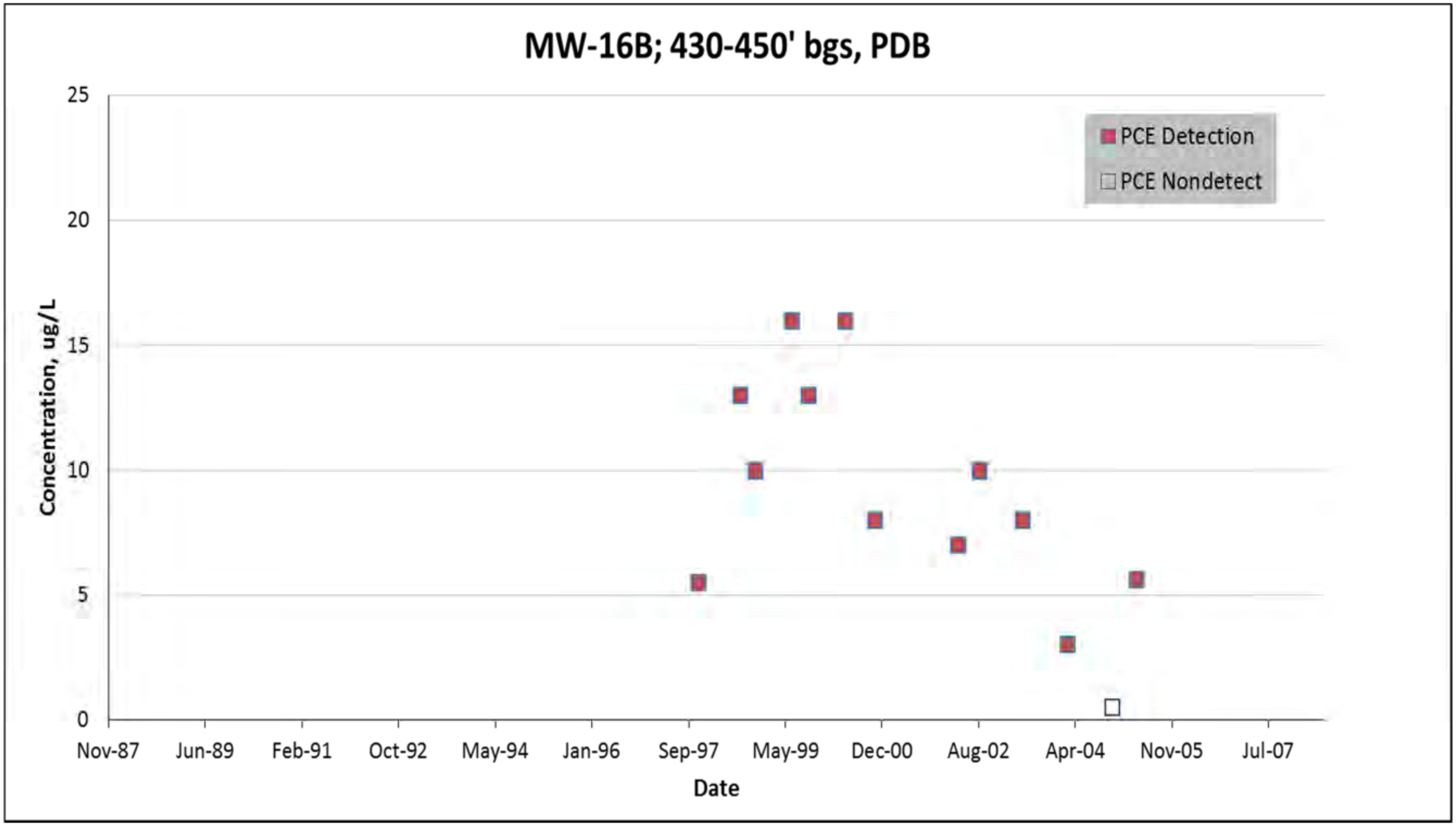

Figure A-33. Time series trend plot of PCE at monitoring well MW-16B. Sample collected 440 ft below ground surface. Sample type is passive diffusion bag.

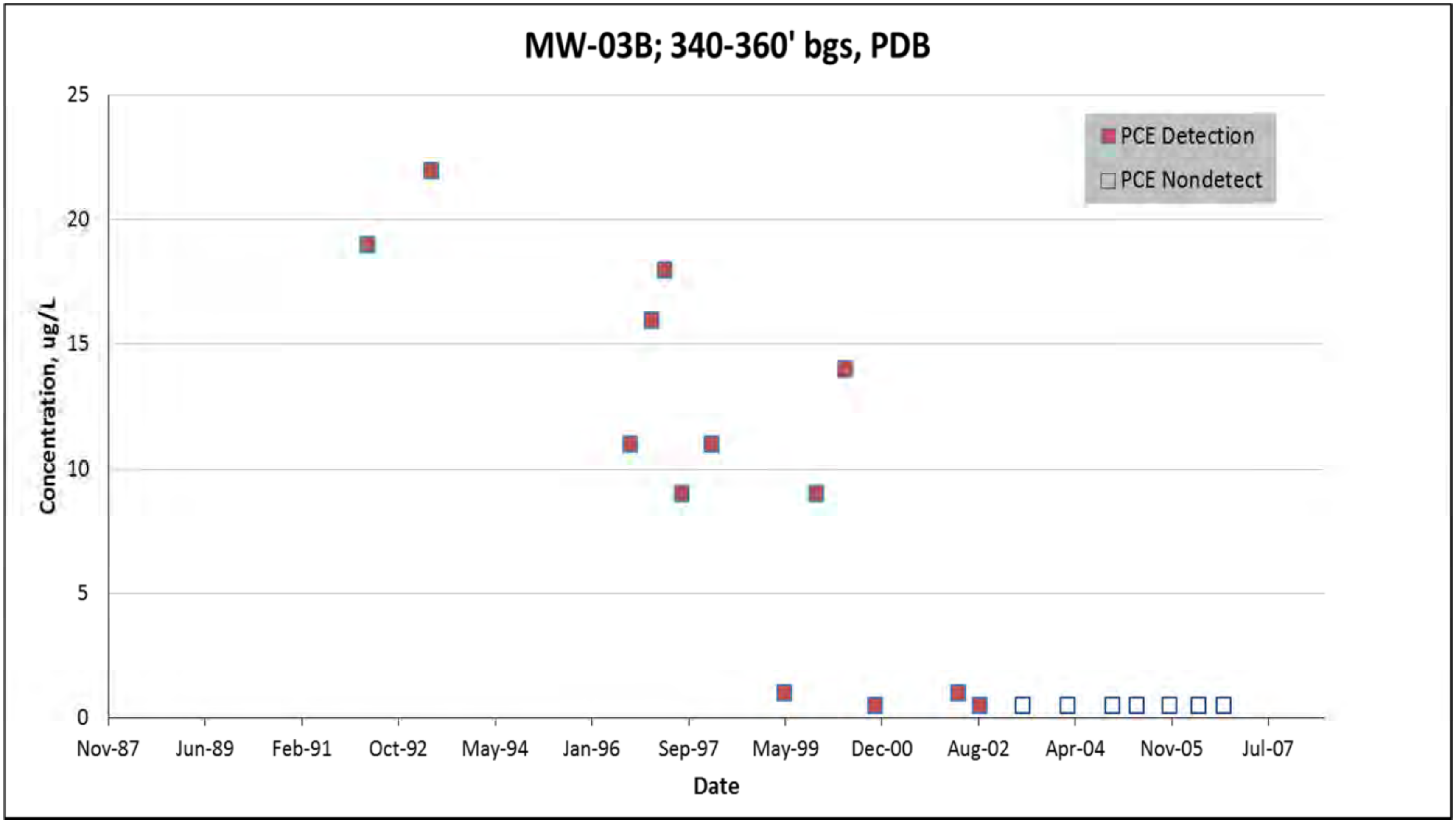

Figure A-34. Time series trend plot of PCE at monitoring well MW-03B. Sample collected 350 ft below ground surface. Sample type is passive diffusion bag.

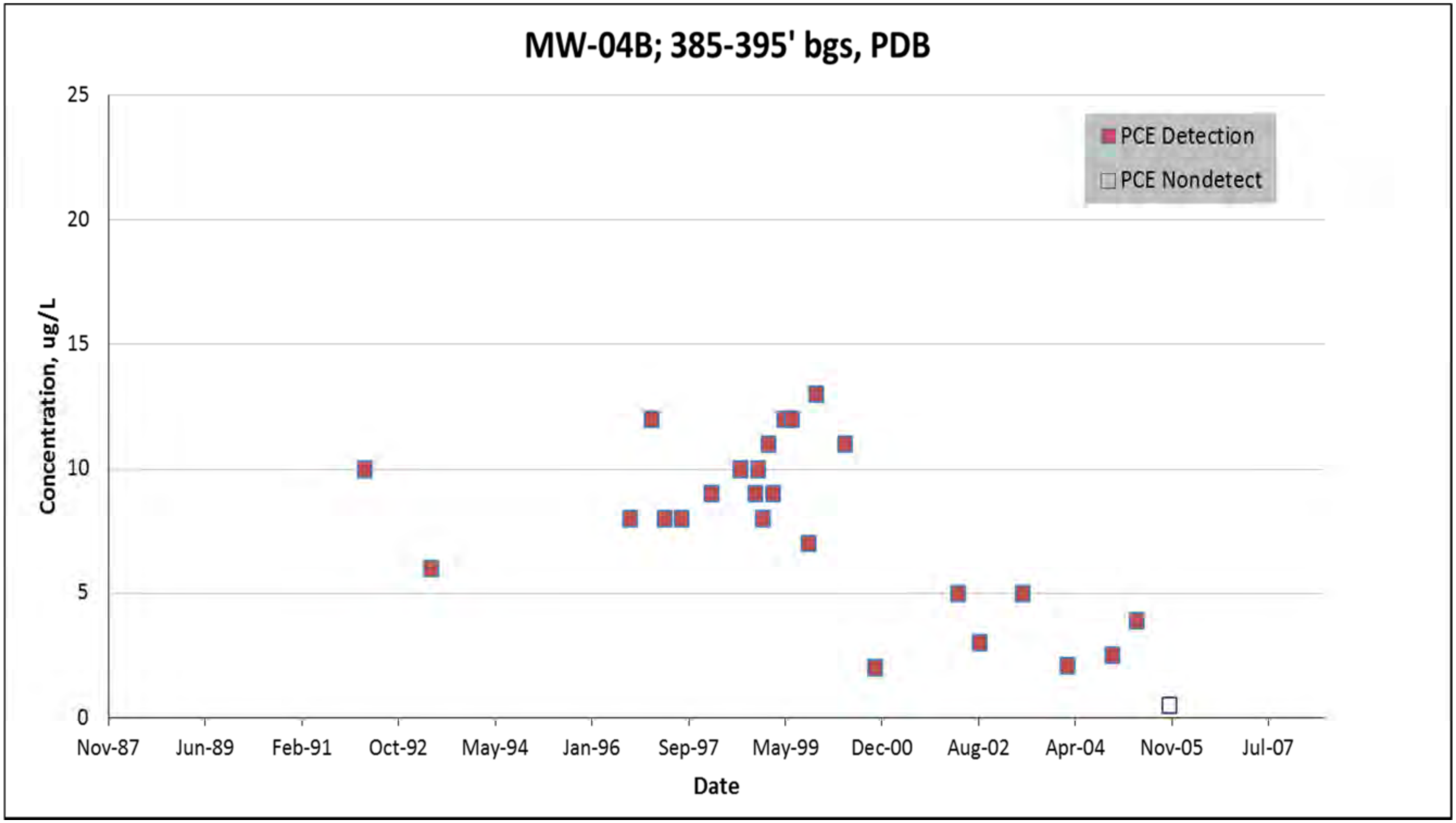

Figure A-35. Time series trend plot of PCE at monitoring well MW-04B. Sample collected 390 ft below ground surface. Sample type is passive diffusion bag.

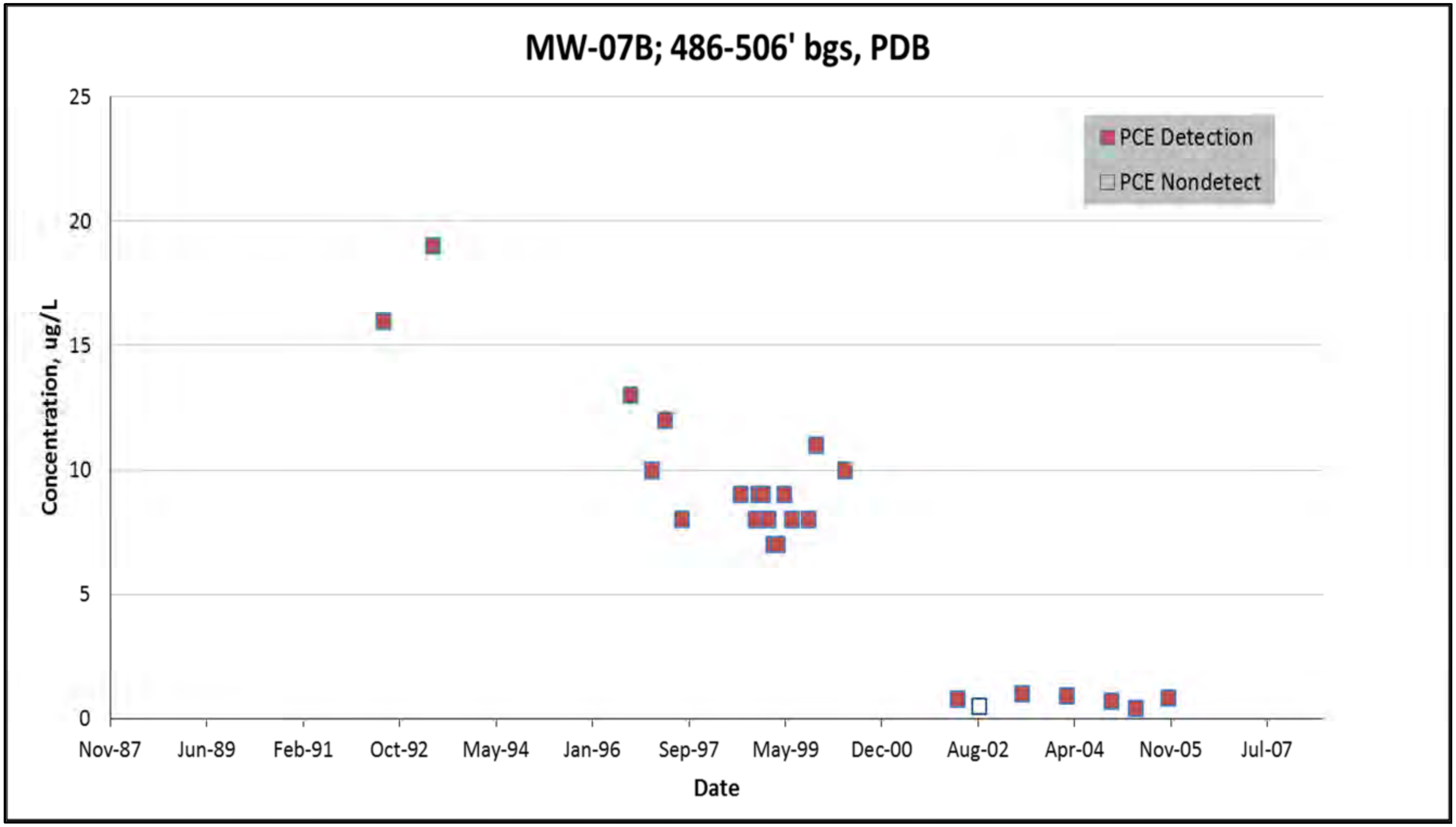

Figure A-36. Time series trend plot of PCE at monitoring well MW-07B. Sample collected 496 ft below ground surface. Sample type is passive diffusion bag.

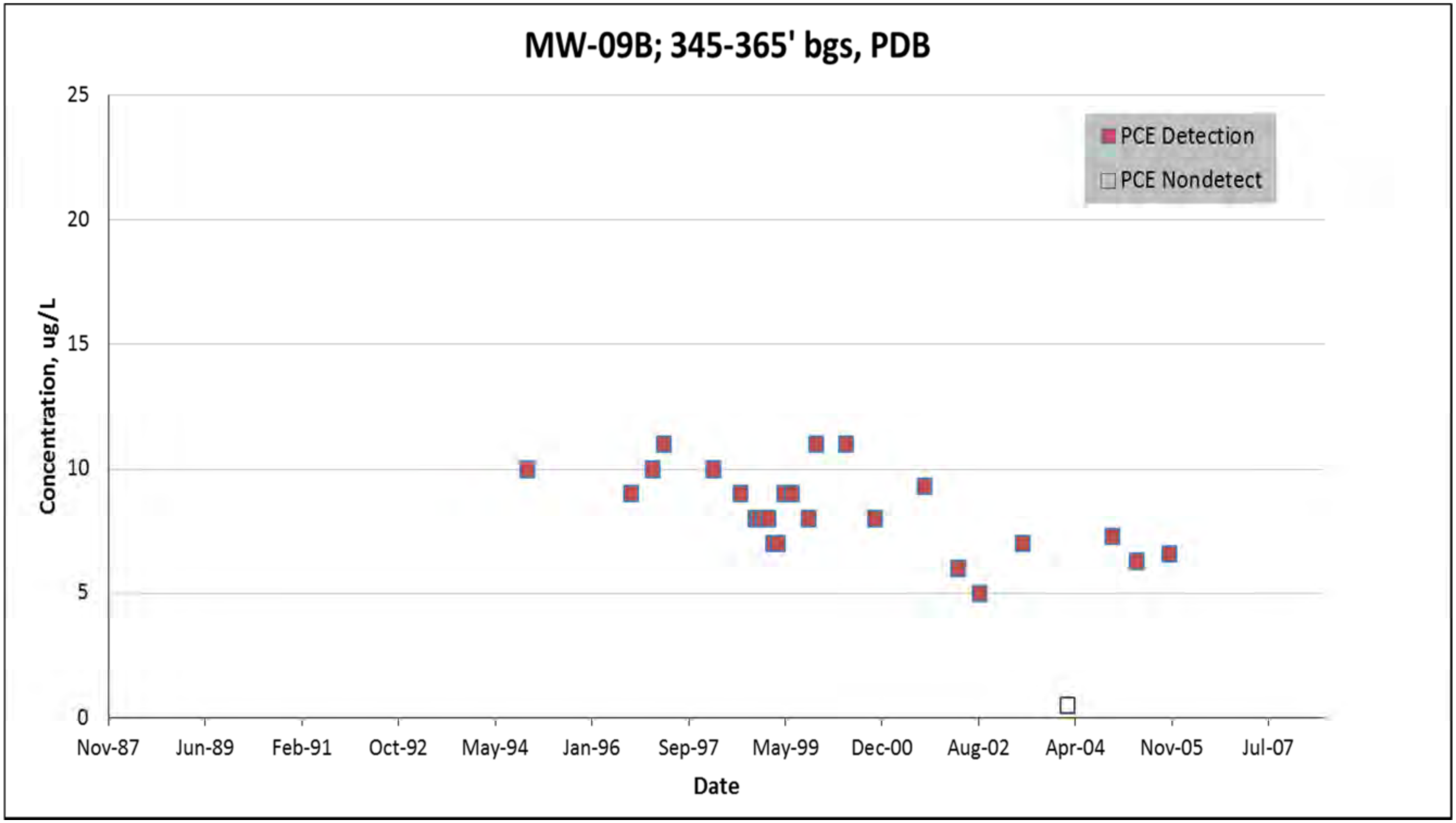

Figure A-37. Time series trend plot of PCE at monitoring well MW-09B. Sample collected 355 ft below ground surface. Sample type is passive diffusion bag.

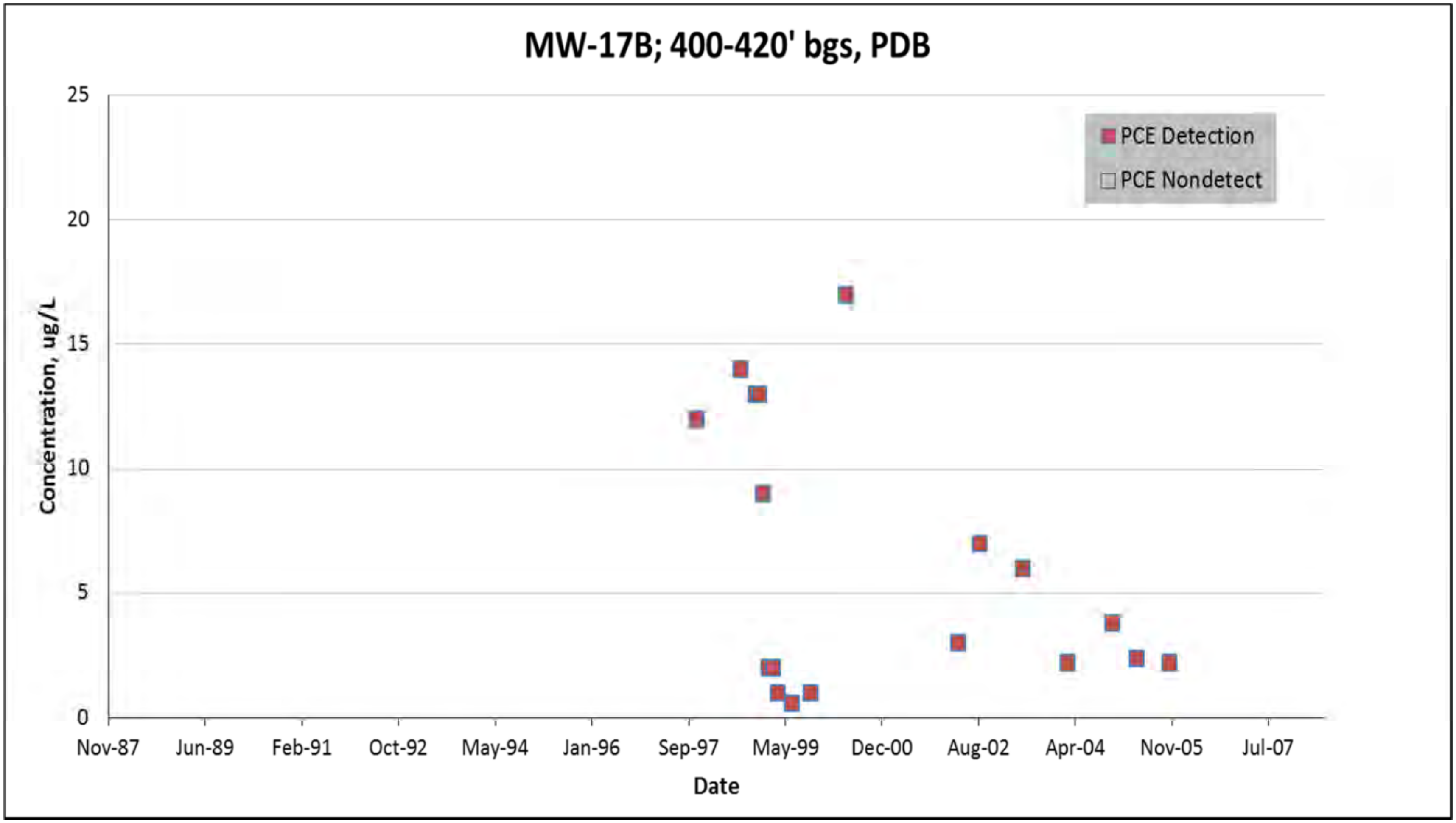

Figure A-38. Time series trend plot of PCE at monitoring well MW-17B. Sample collected 410 ft below ground surface. Sample type is passive diffusion bag.

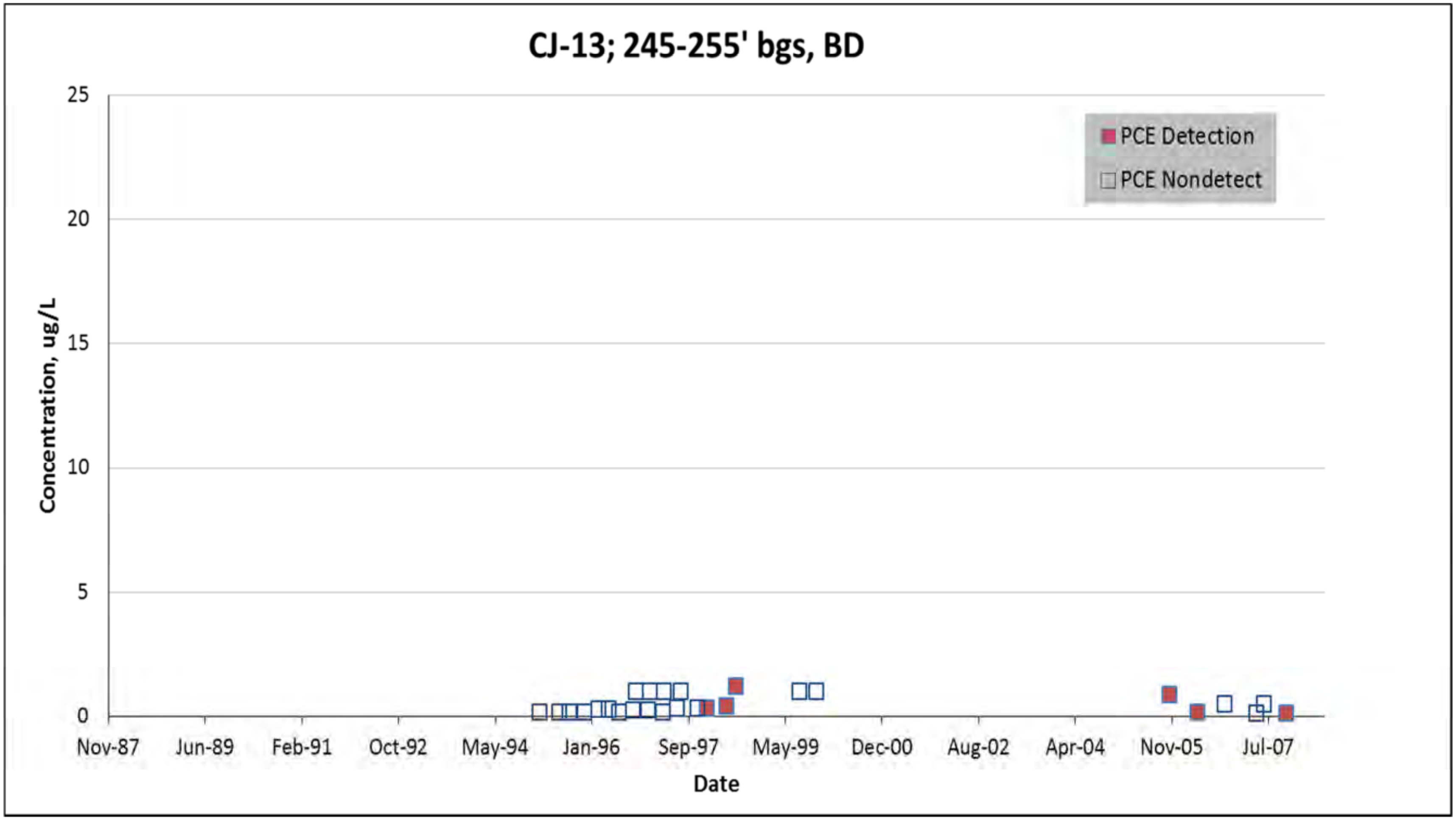

Figure A-39. Time series trend plot of PCE at monitoring well CJ-13. Sample collected 245-255 ft below ground surface. Sample type is bailer.

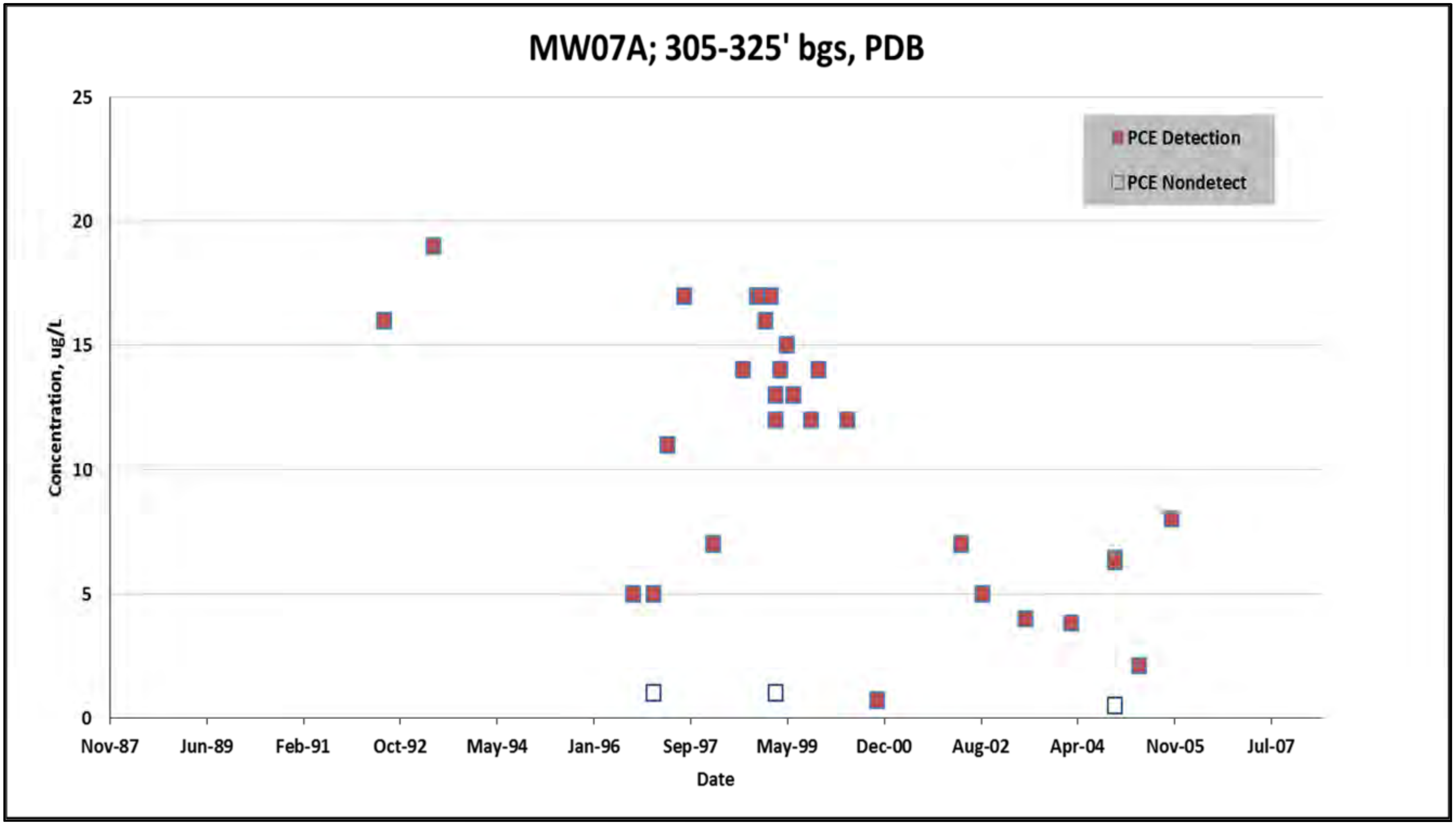

Figure A-40. Time series trend plot of PCE at monitoring well MW07A. Sample collected 315 ft below ground surface. Sample type is passive diffusion bag.

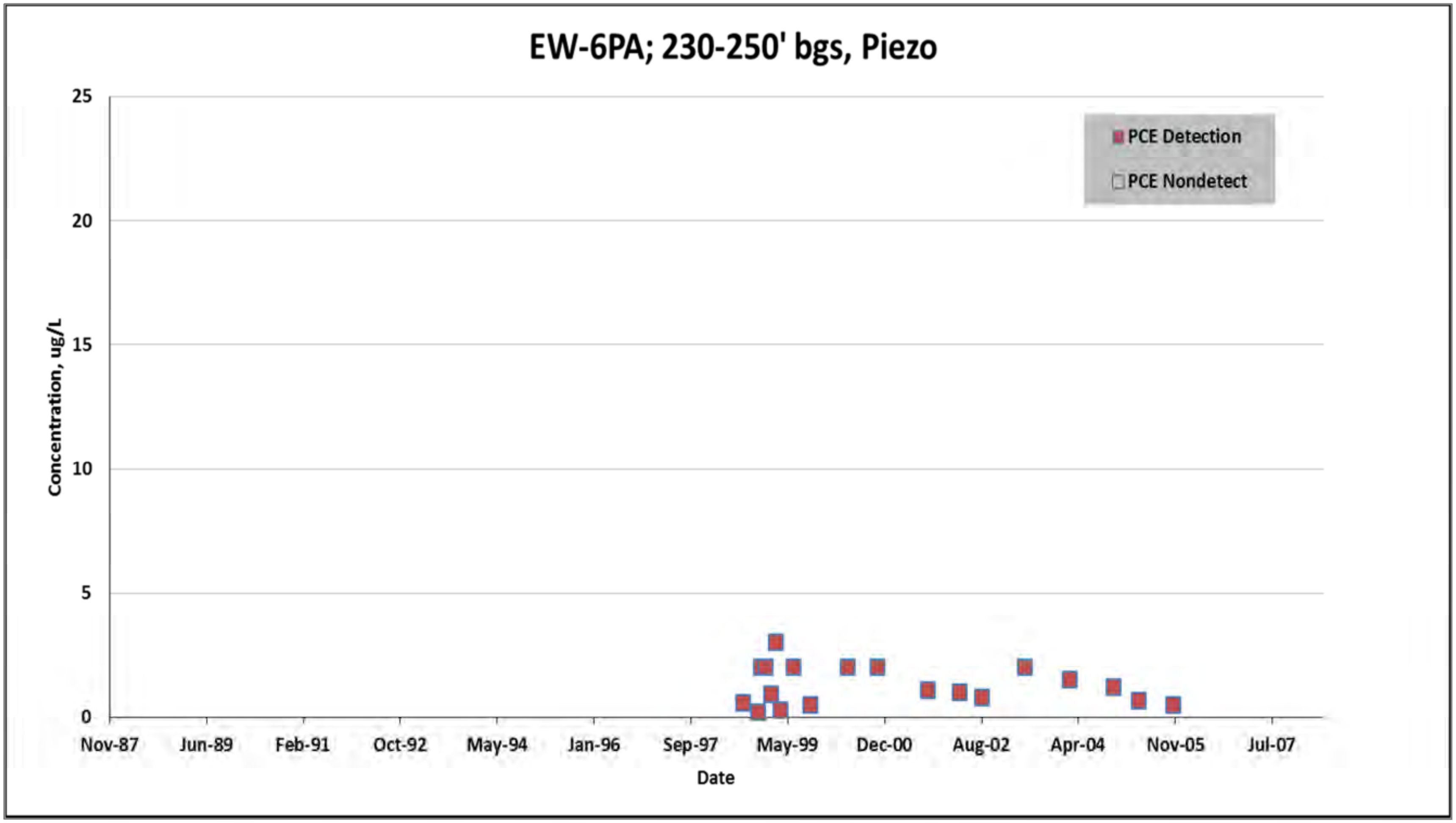

Figure A-41. Time series trend plot of PCE at monitoring well EW-6PA. Sample collected 240 ft below ground surface. Sample type is piezometer.

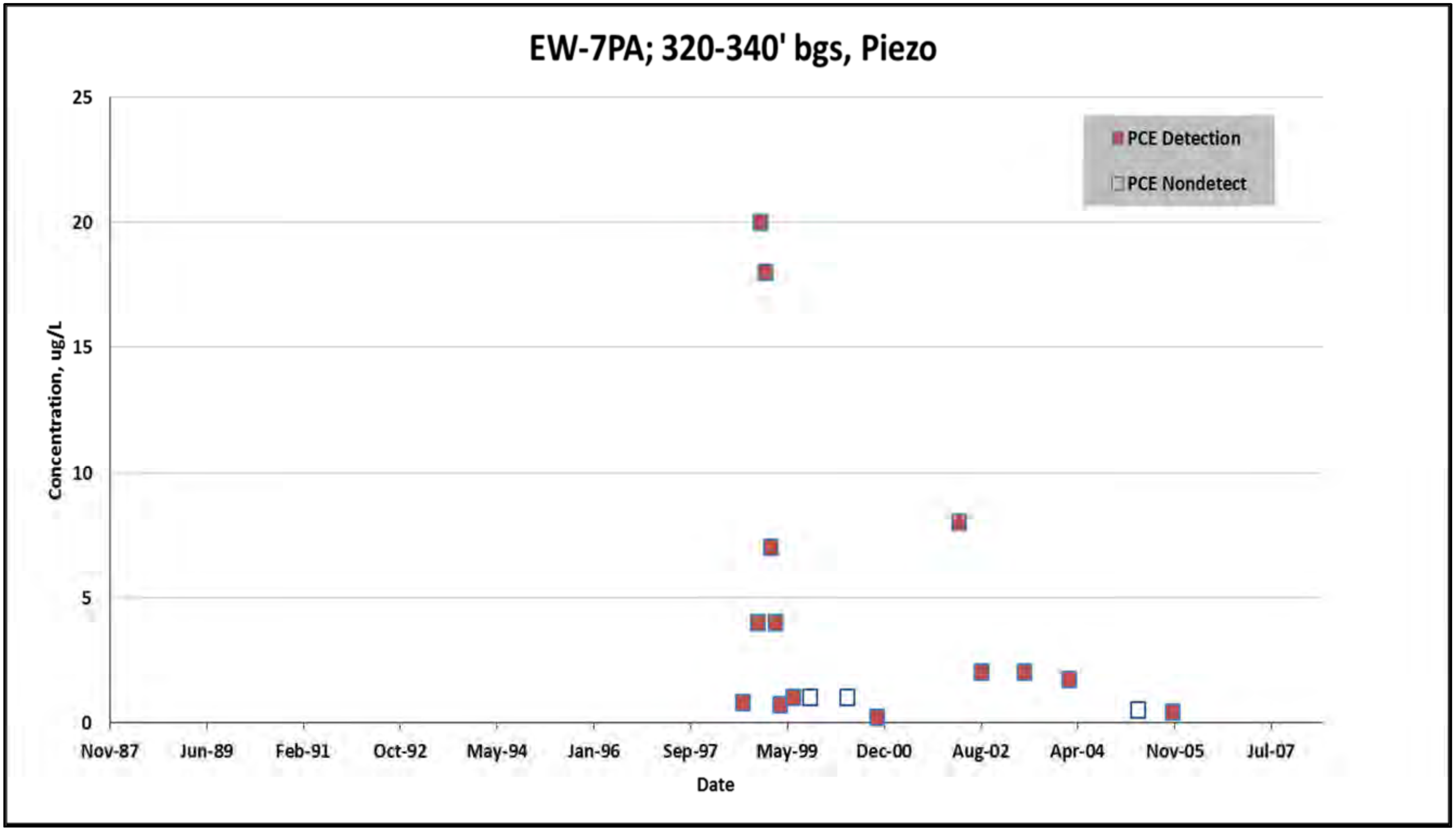

Figure A-42. Time series trend plot of PCE at monitoring well EW-7PA. Sample collected 330 ft below ground surface. Sample type is piezometer.

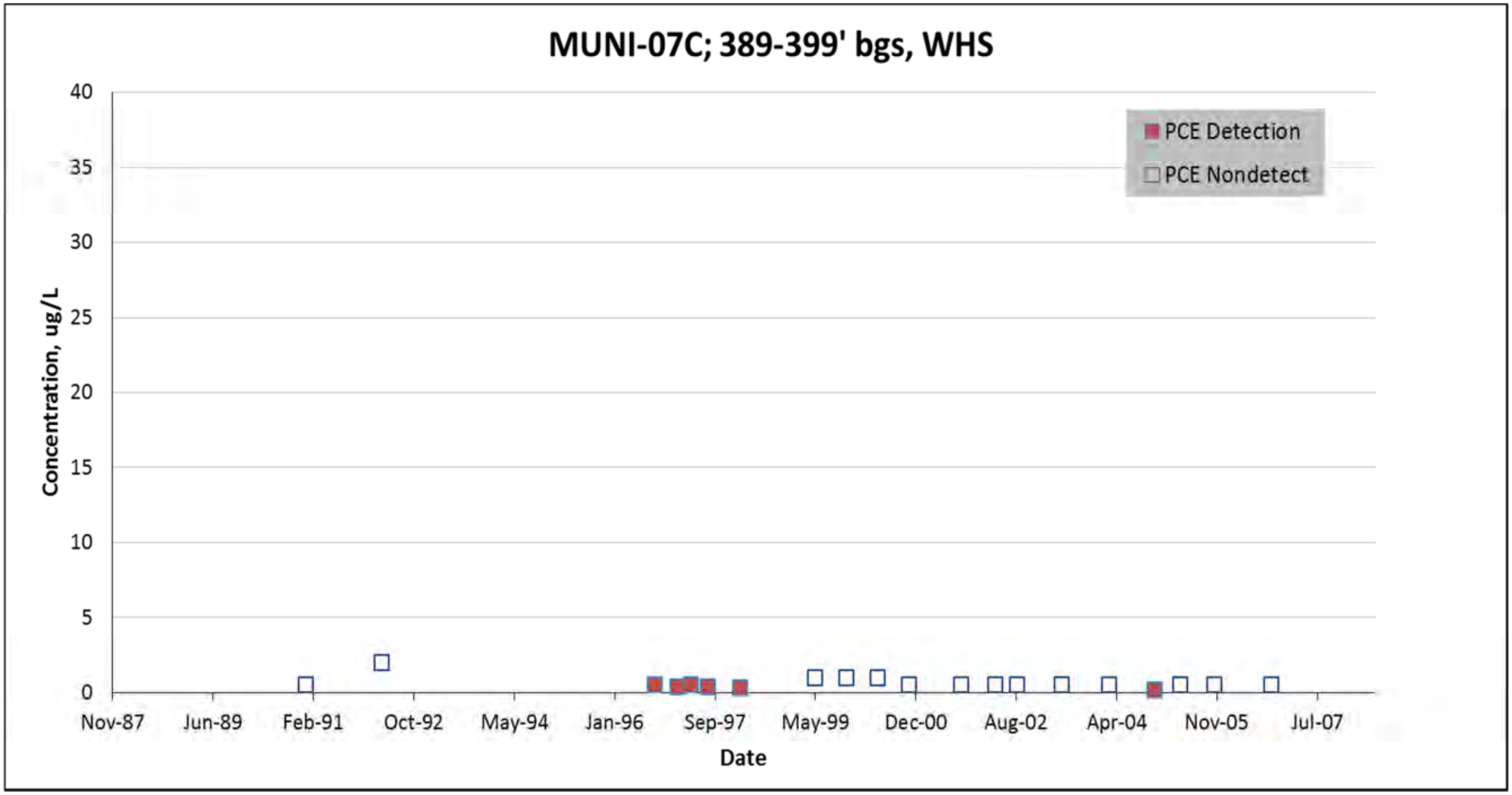

Figure A-43. Time series trend plot of PCE at well MUNI-07C. Sample collected 389-399 ft below ground surface. Sample type is well head spigot.

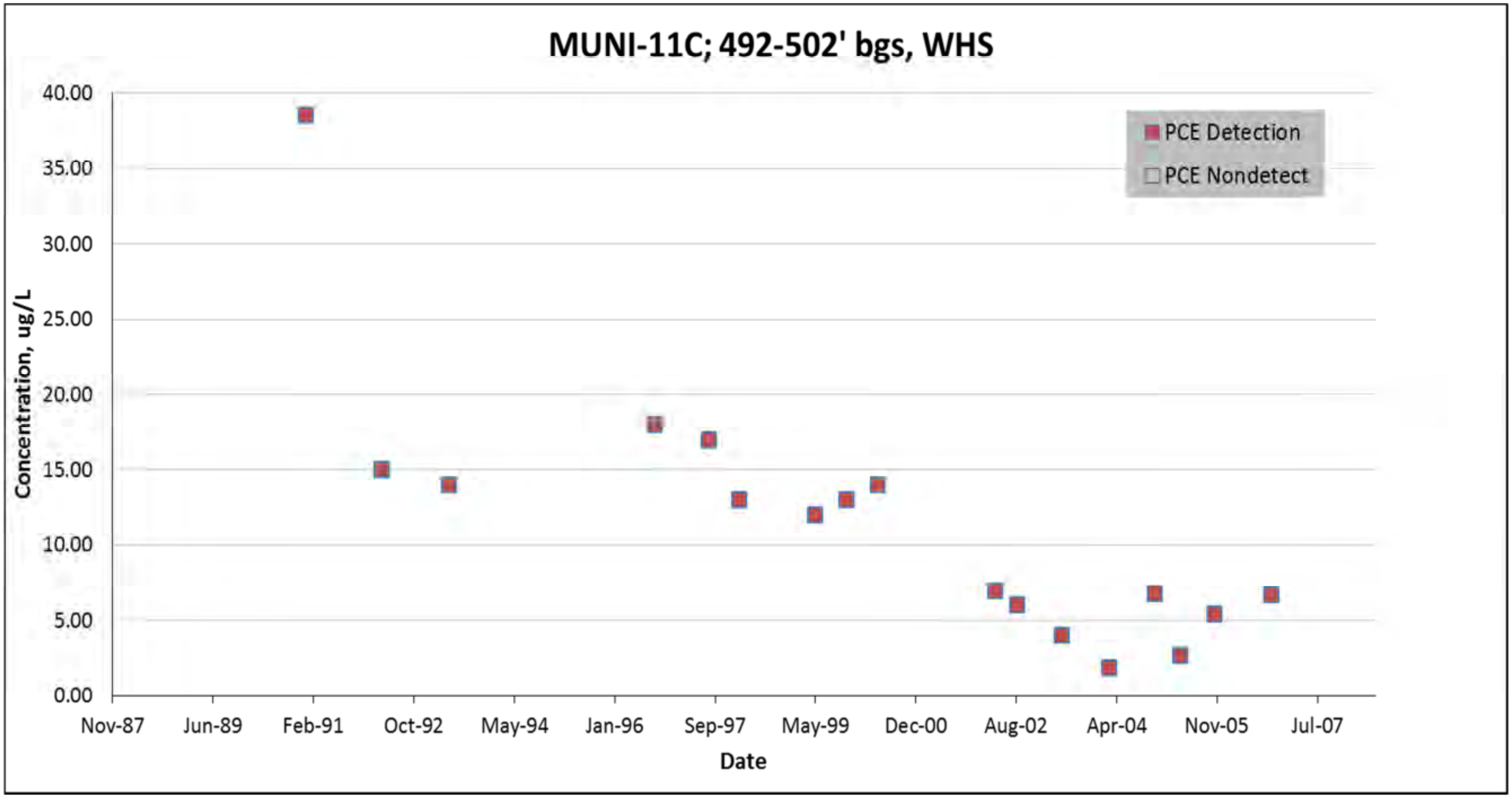

Figure A-44. Time series trend plot of PCE at well MUNI-11C. Sample collected 492-502 ft below ground surface. Sample type is well head spigot.

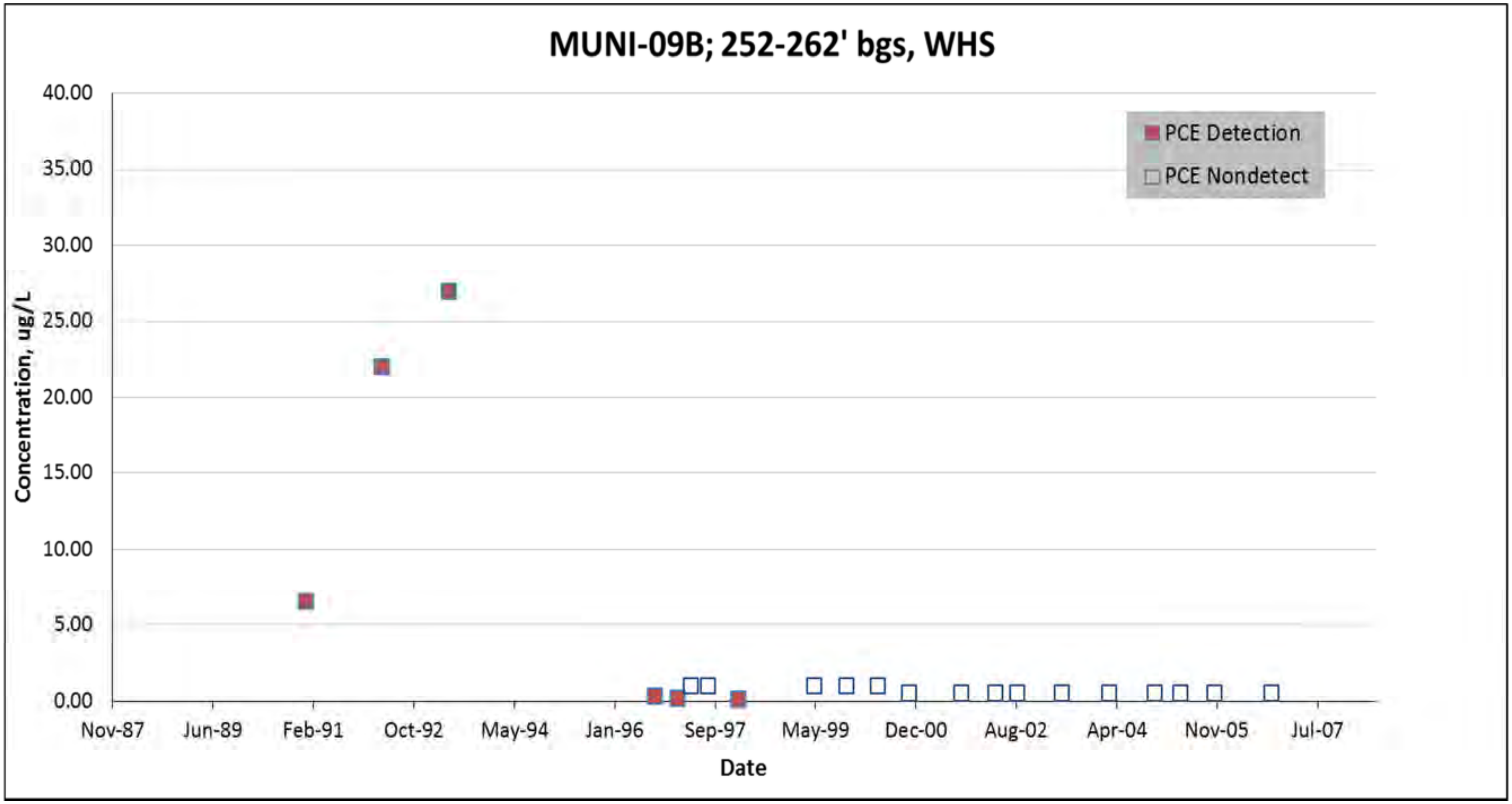

Figure A-45. Time series trend plot of PCE at well MUNI-09B. Sample collected 252-262 ft below ground surface. Sample type is well head spigot.

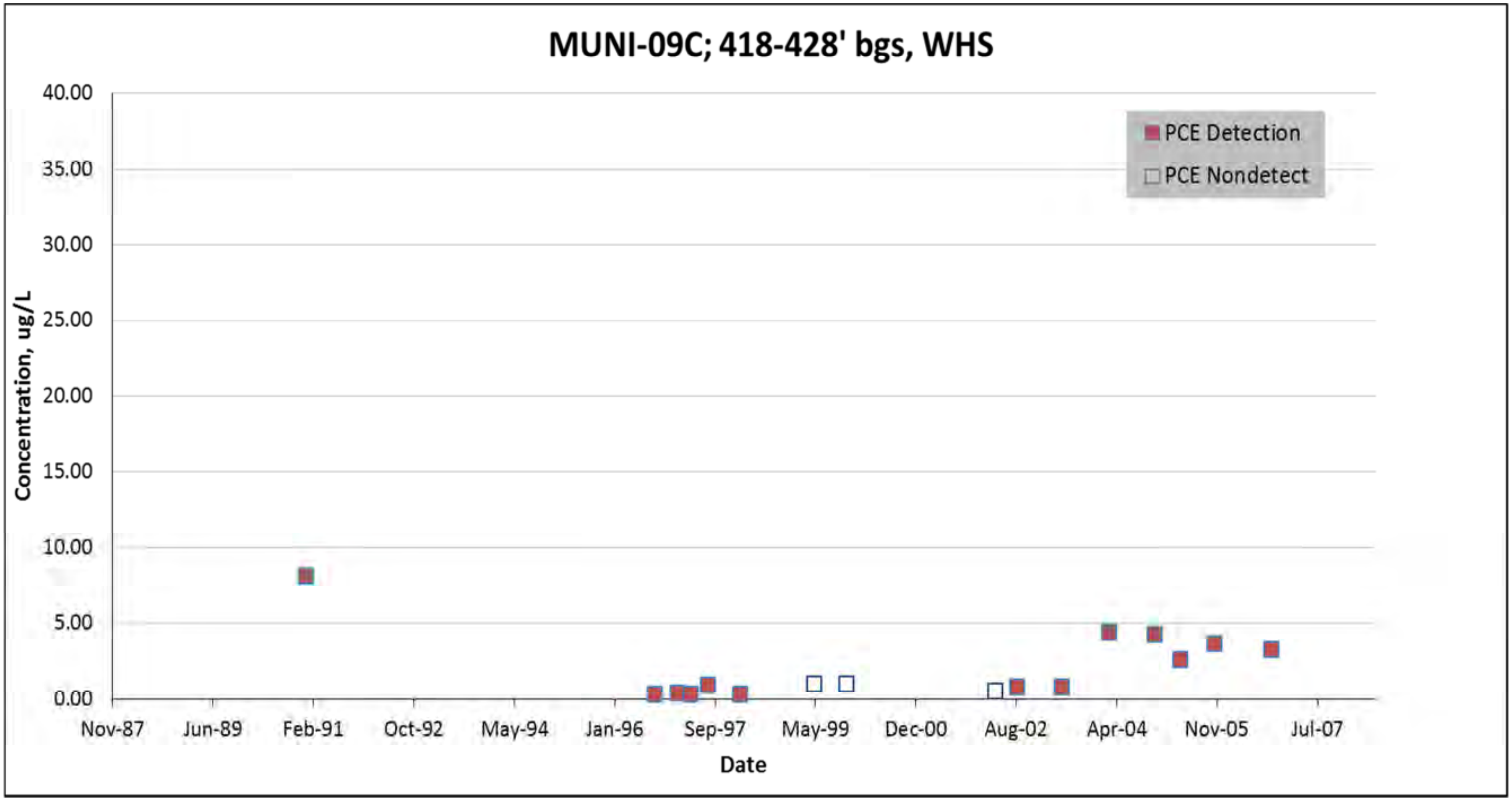

Figure A-46. Time series trend plot of PCE at well MUNI-09C. Sample collected 418-428 ft below ground surface. Sample type is well head spigot.

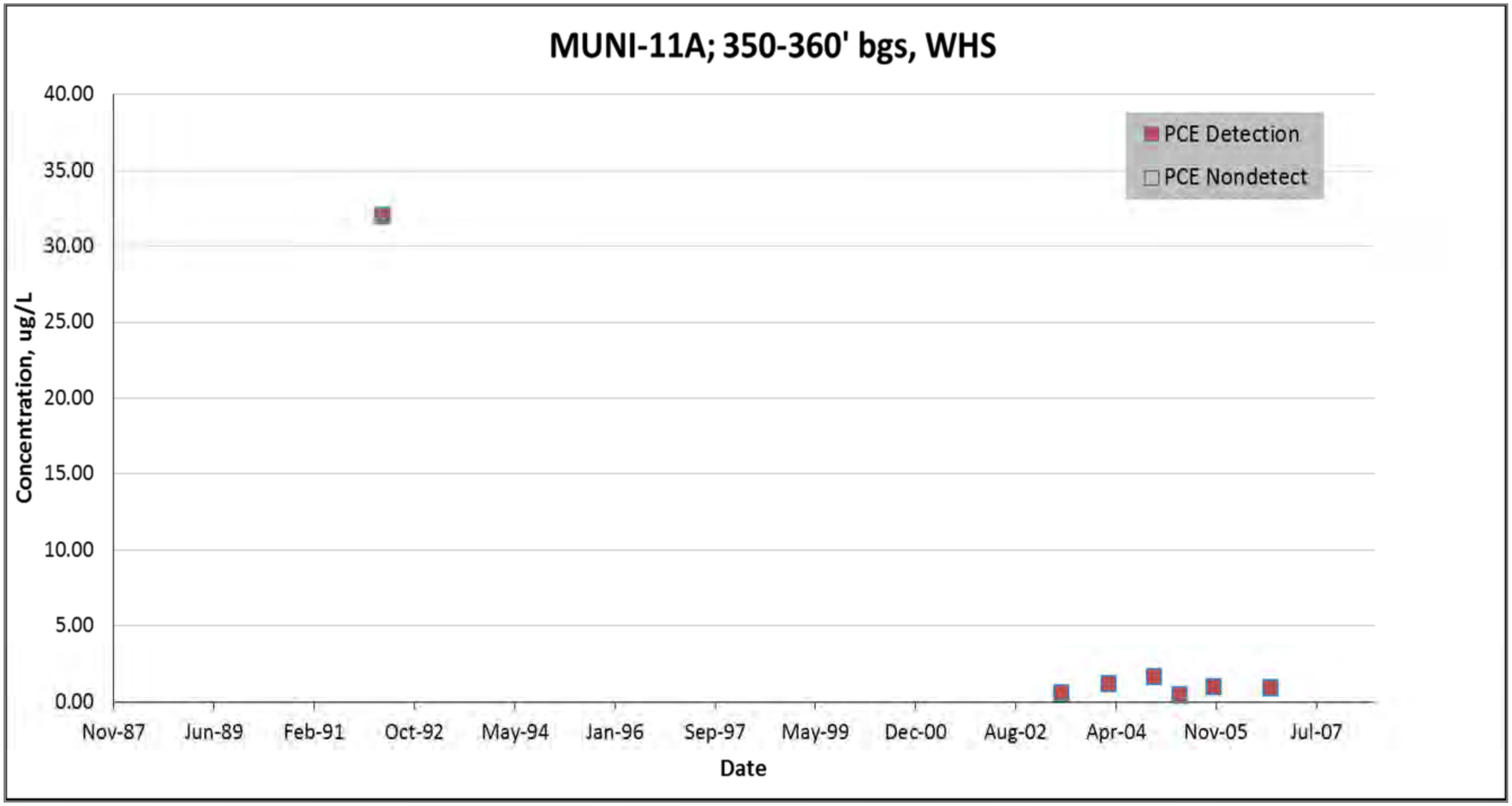

Figure A-47. Time series trend plot of PCE at well MUNI-11A. Sample collected 350-360 ft below ground surface. Sample type is well head spigot.

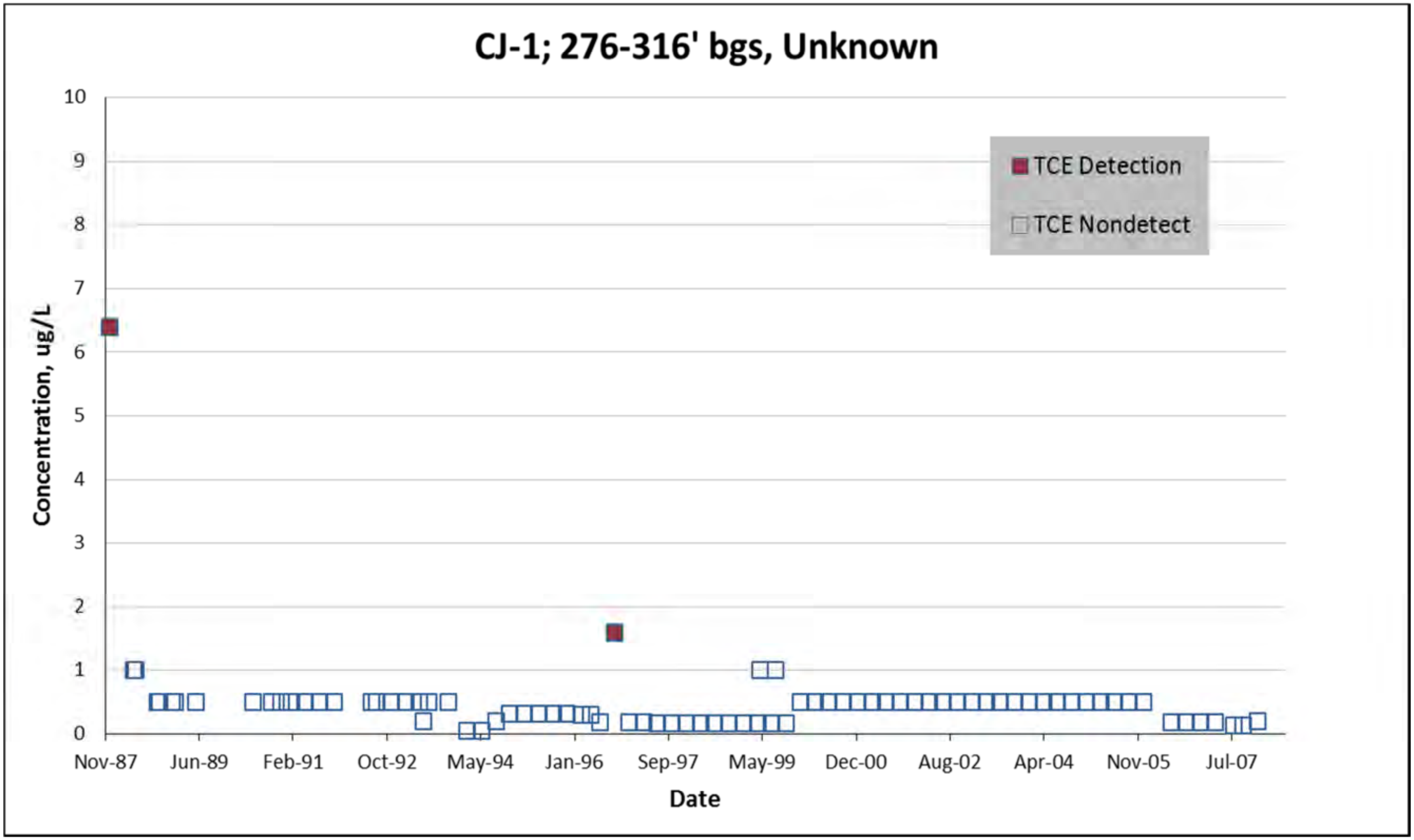

Figure A-48. Time series trend plot of TCE at monitoring well CJ-1. Sample collected 276-316 ft below ground surface. Sample type is well Redi-Flo 4.

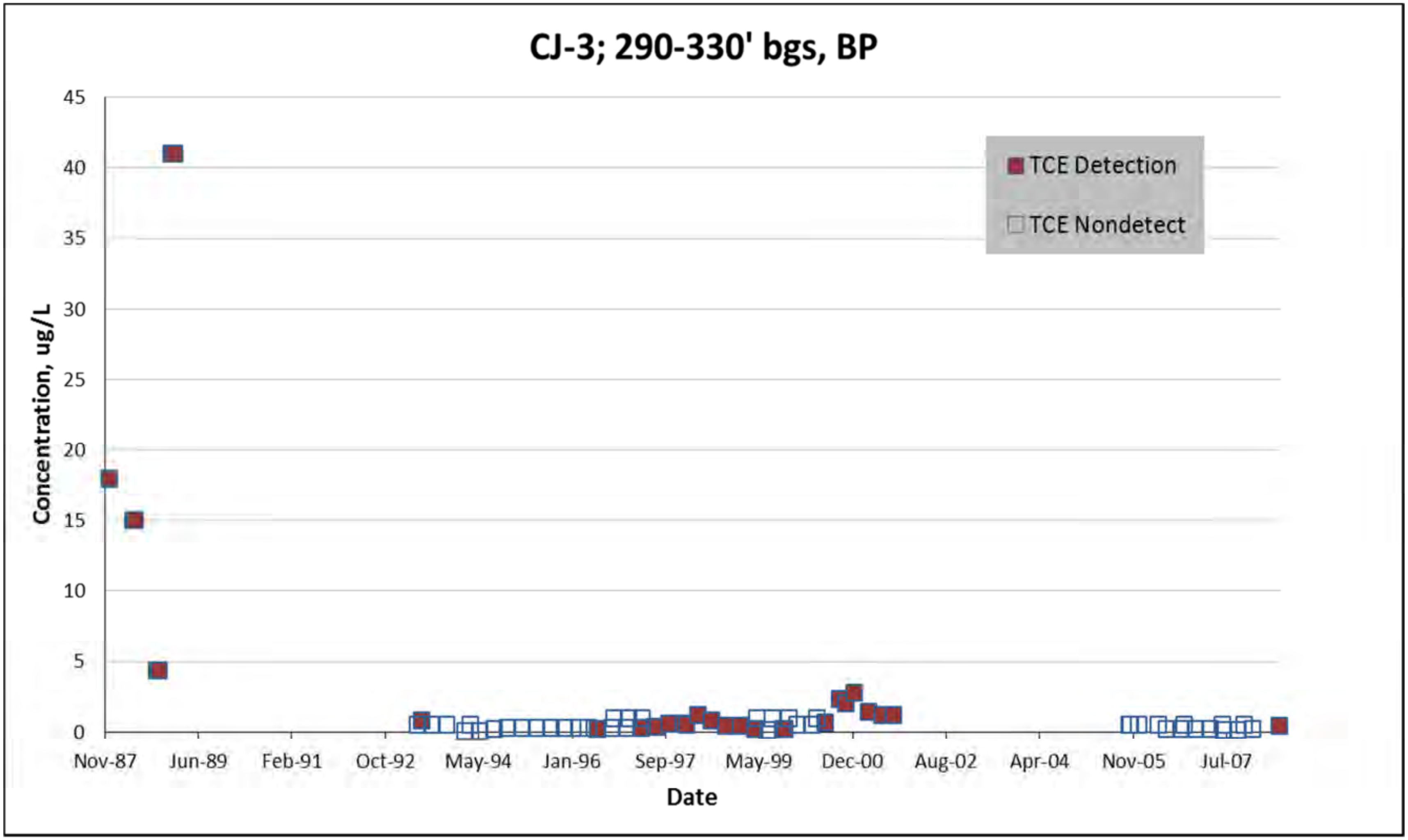

Figure A-49. Time series trend plot of TCE at monitoring well CJ-3. Sample collected 290-330 ft below ground surface. Sample type is Redi-Flo 4.

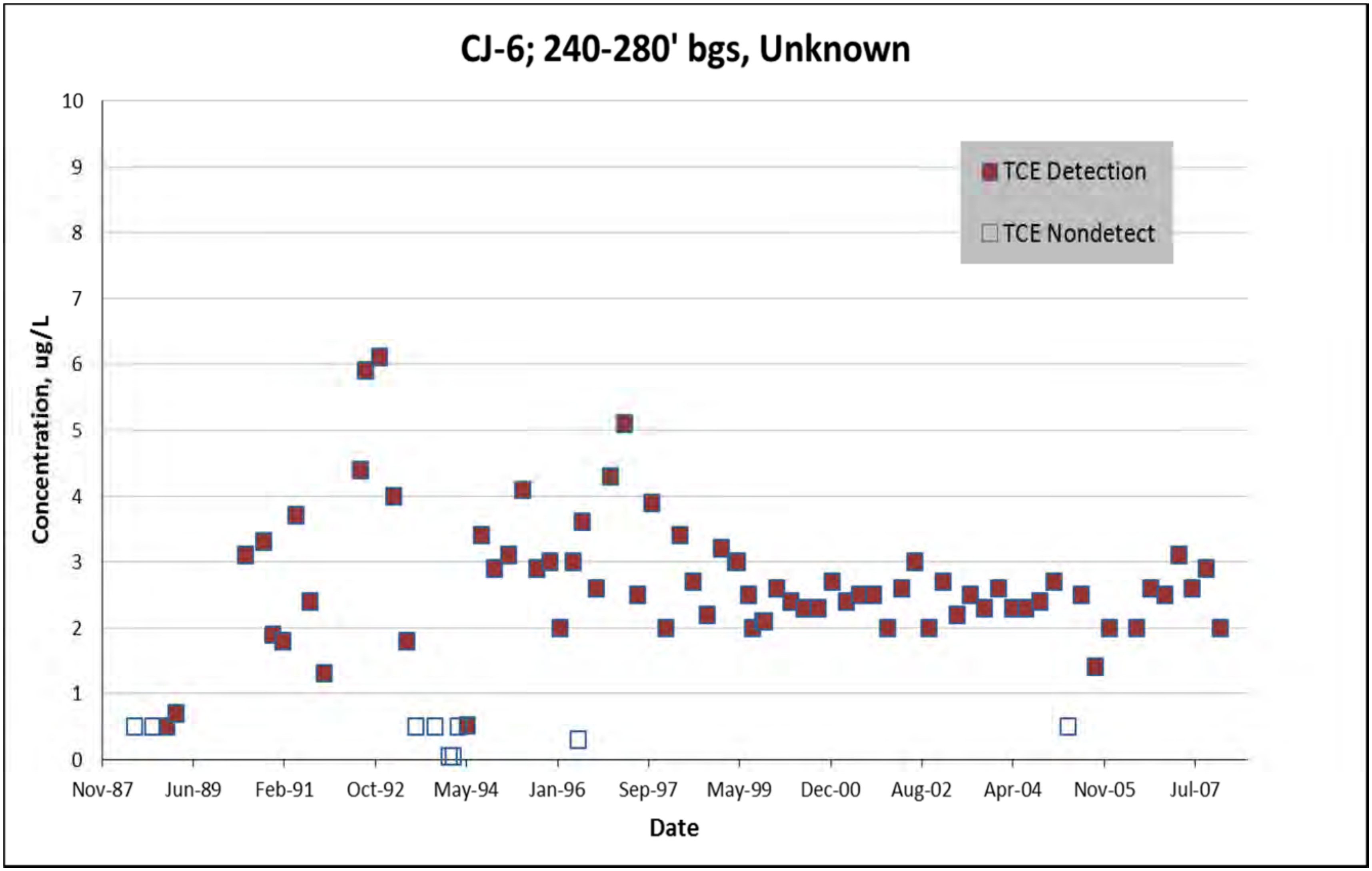

Figure A-50. Time series trend plot of TCE at monitoring well CJ-6. Sample collected 240-280 ft below ground surface. Sample type is Redi-Flo 2.

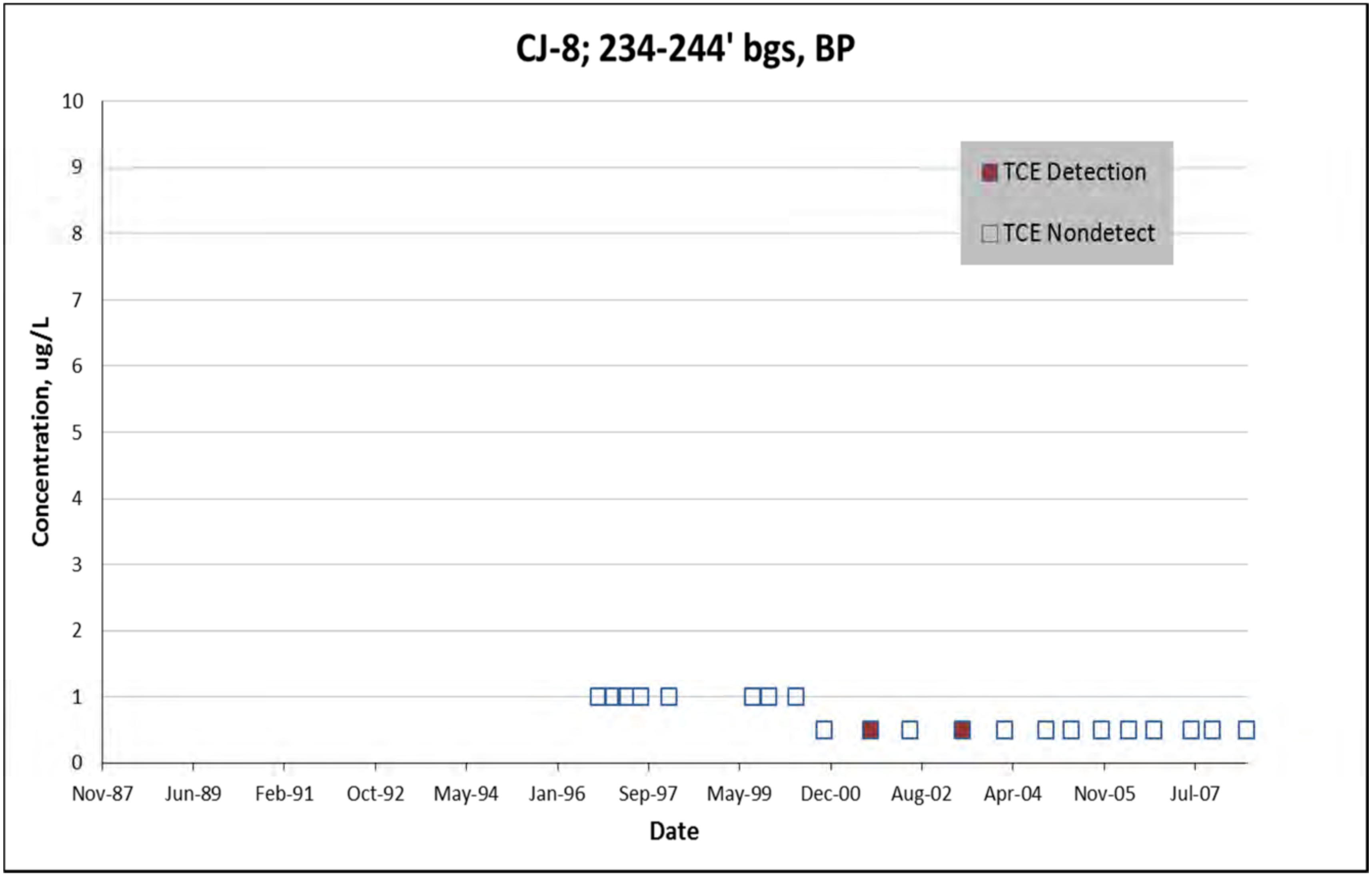

Figure A-51. Time series trend plot of TCE at monitoring well CJ-8. Sample collected 234-244 ft below ground surface. Sample type is bladder pump.

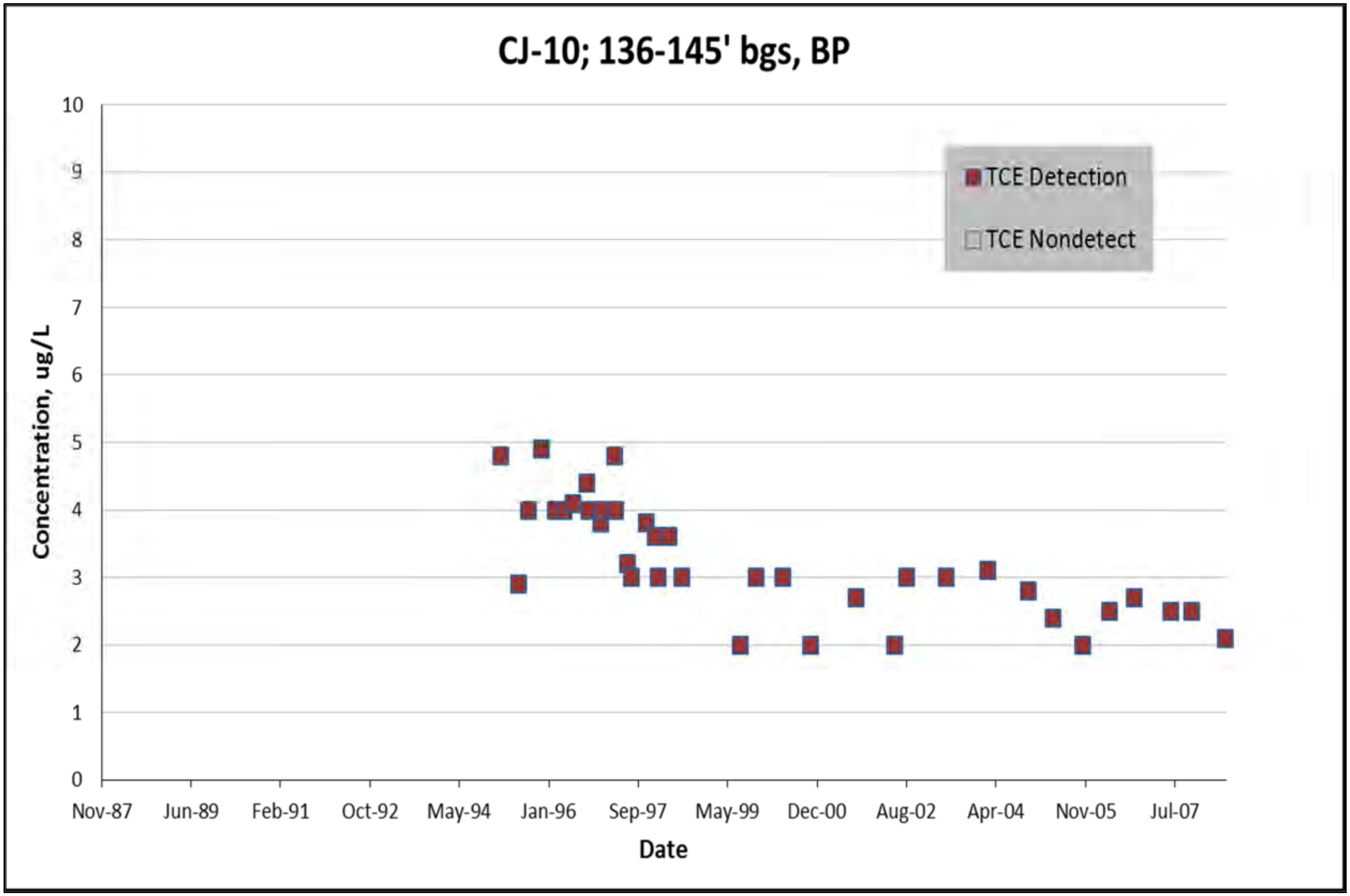

Figure A-52. Time series trend plot of TCE at monitoring well CJ-10. Sample collected 136-145 ft below ground surface. Sample type is bladder pump.

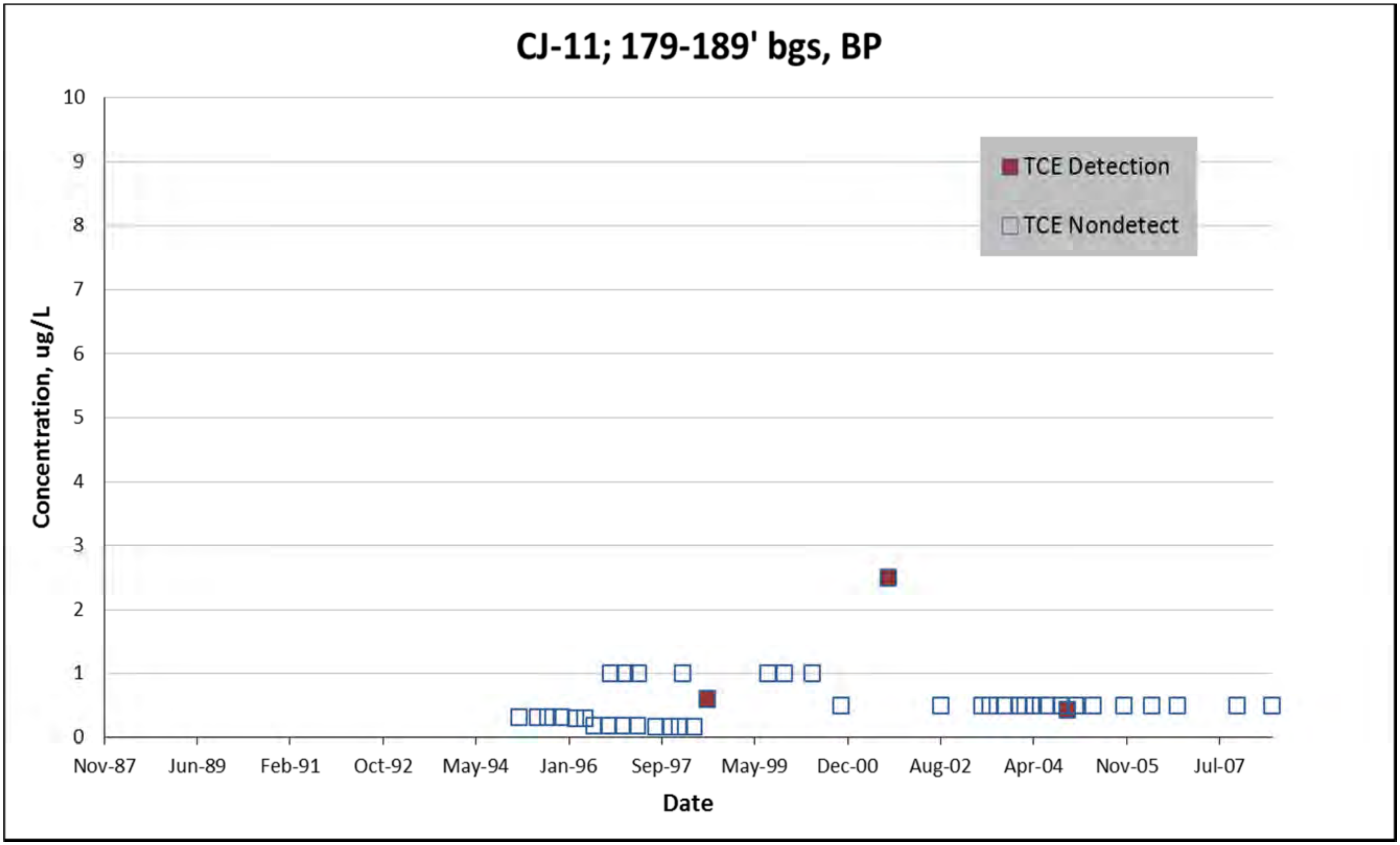

Figure A-53. Time series trend plot of TCE at monitoring well CJ-11. Sample collected 179-189 ft below ground surface. Sample type is bladder pump.

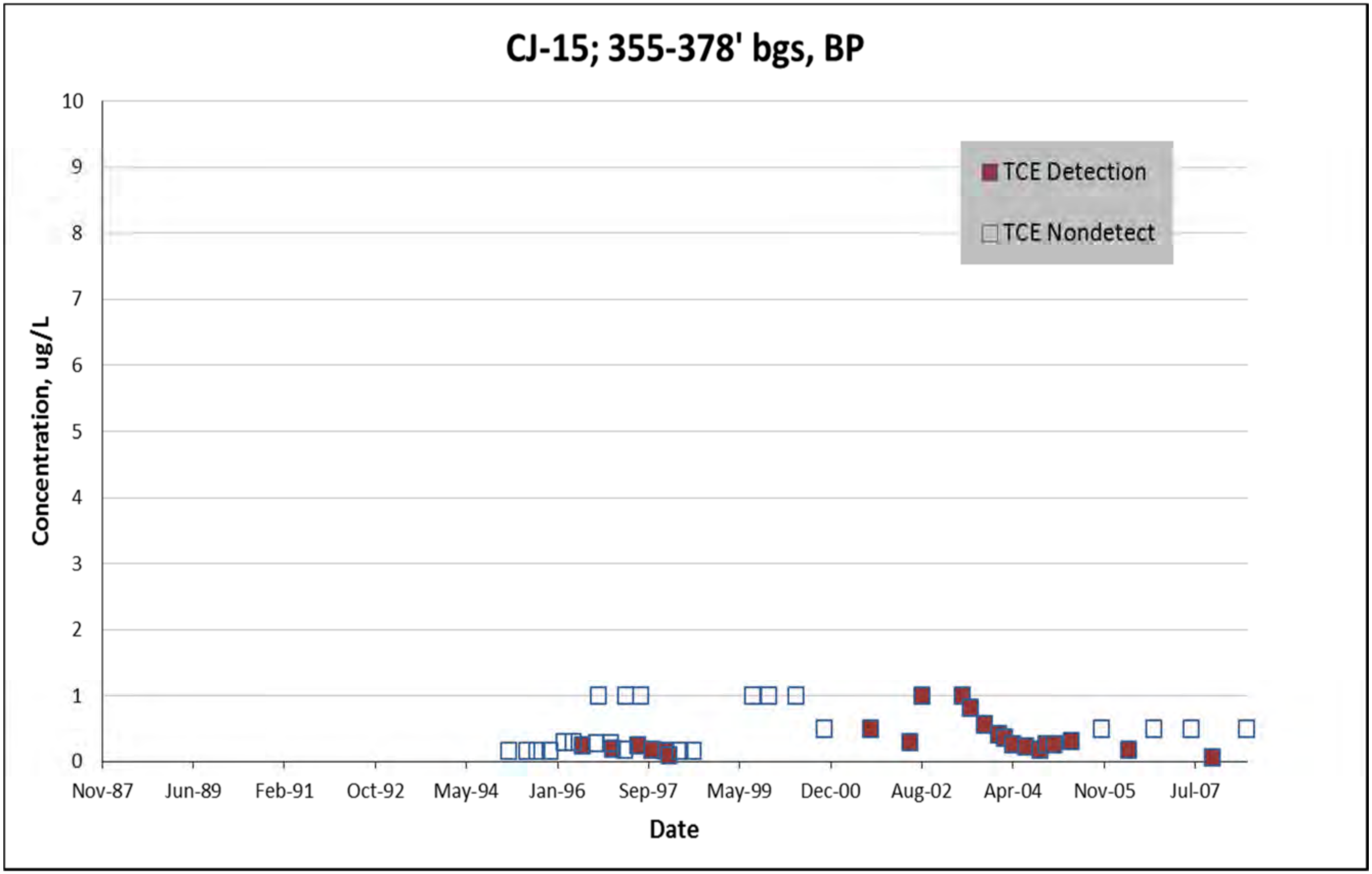

Figure A-54. Time series trend plot of TCE at monitoring well CJ-15. Sample collected 355-378 ft below ground surface. Sample type is Redi-Flo 4.

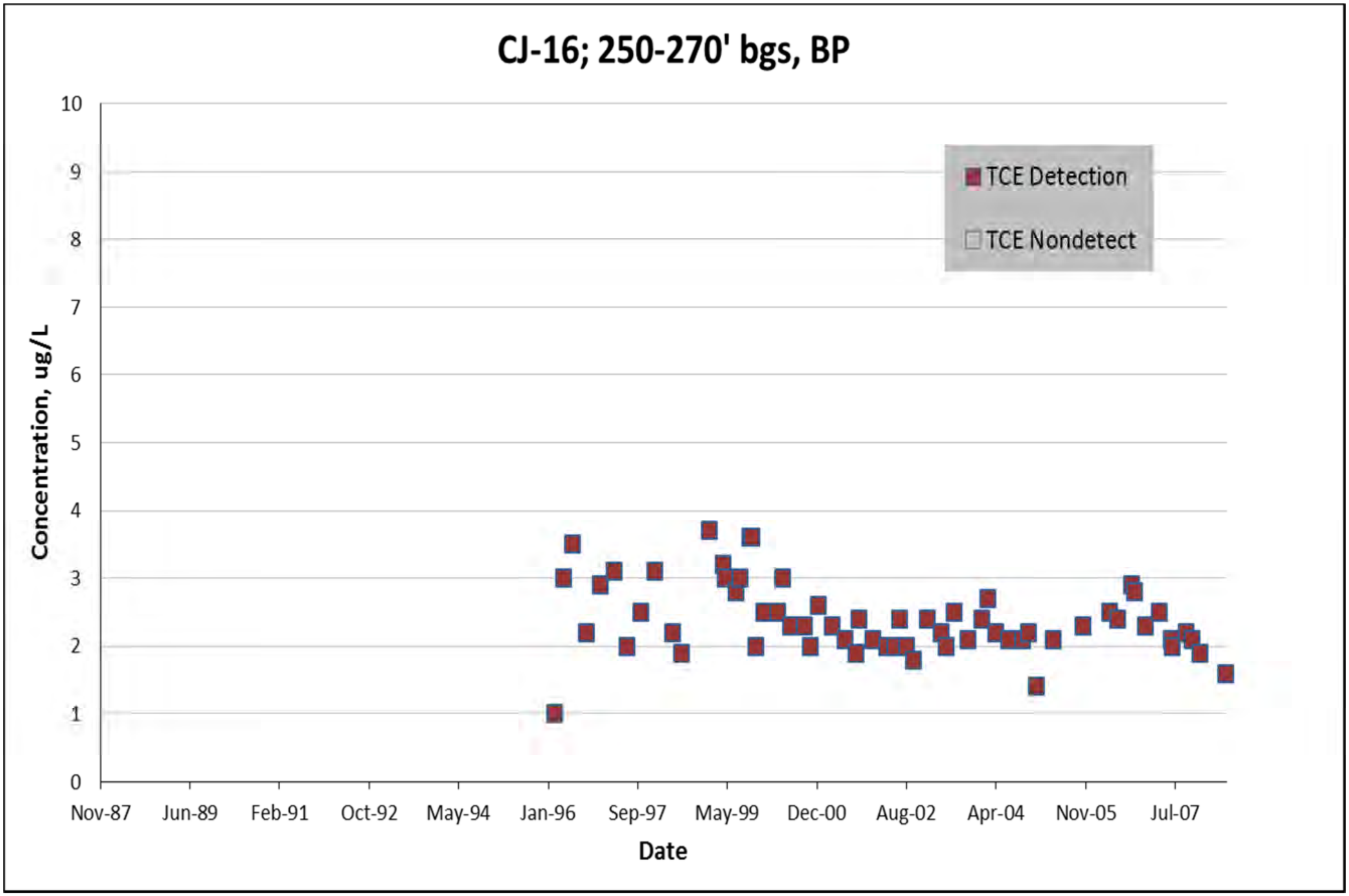

Figure A-55. Time series trend plot of TCE at monitoring well CJ-16. Sample collected 250-270 ft below ground surface. Sample type is Redi-Flo 2.

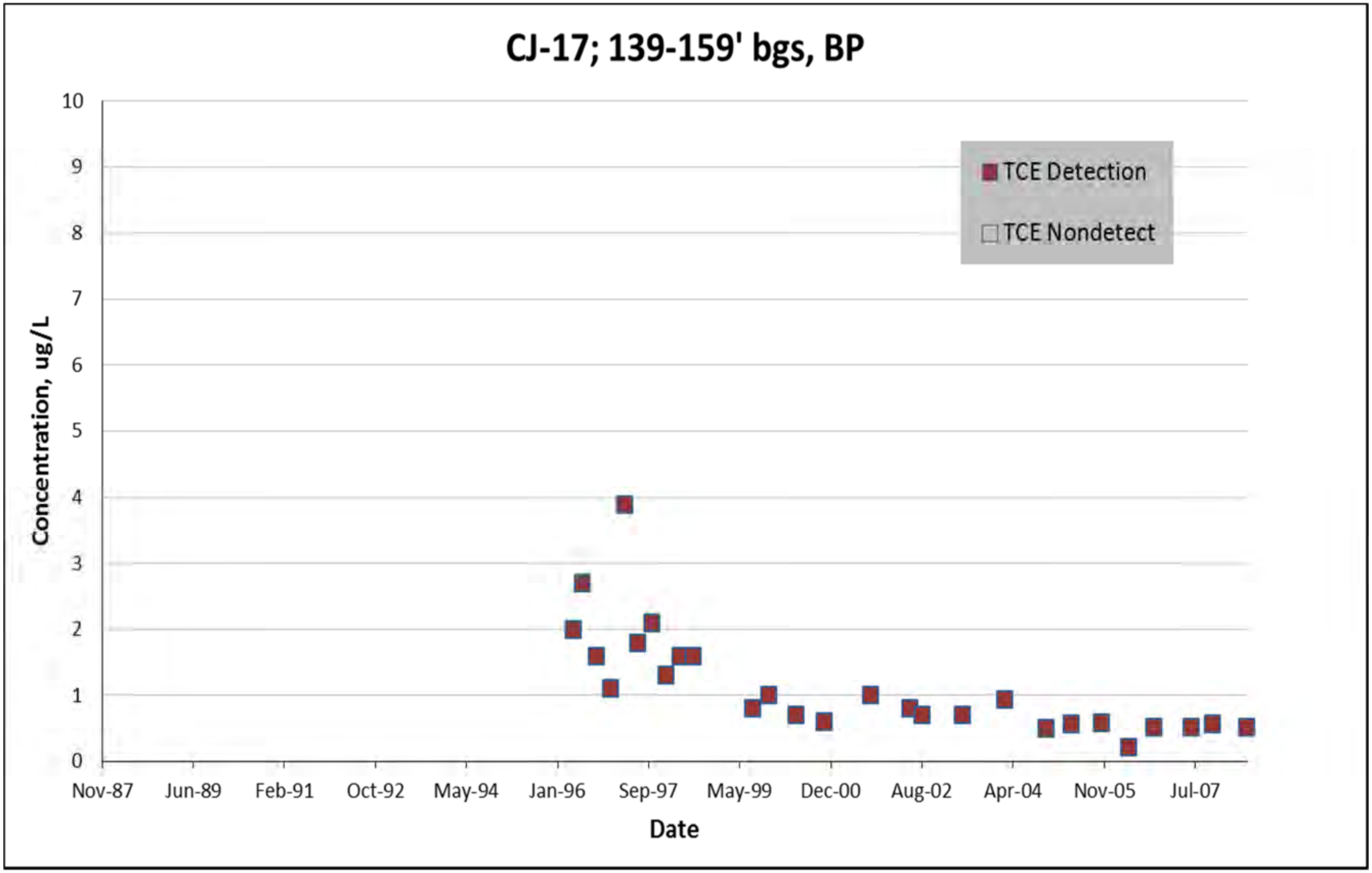

Figure A-56. Time series trend plot of TCE at monitoring well CJ-17. Sample collected 139-159 ft below ground surface. Sample type is Redi-Flo 2.

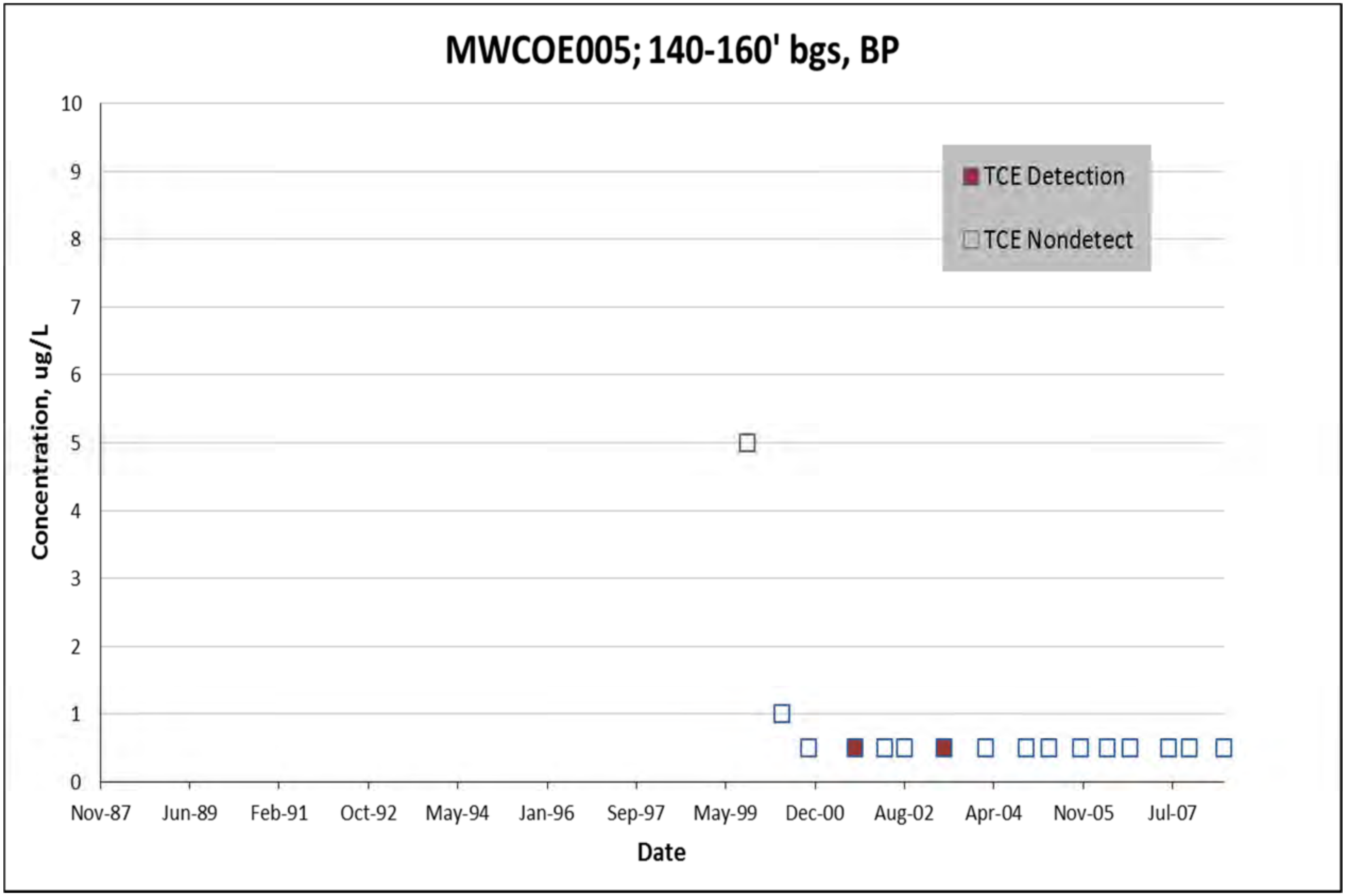

Figure A-57. Time series trend plot of TCE at monitoring well MWCOE005. Sample collected 150 ft below ground surface. Sample type is passive diffusion bag.

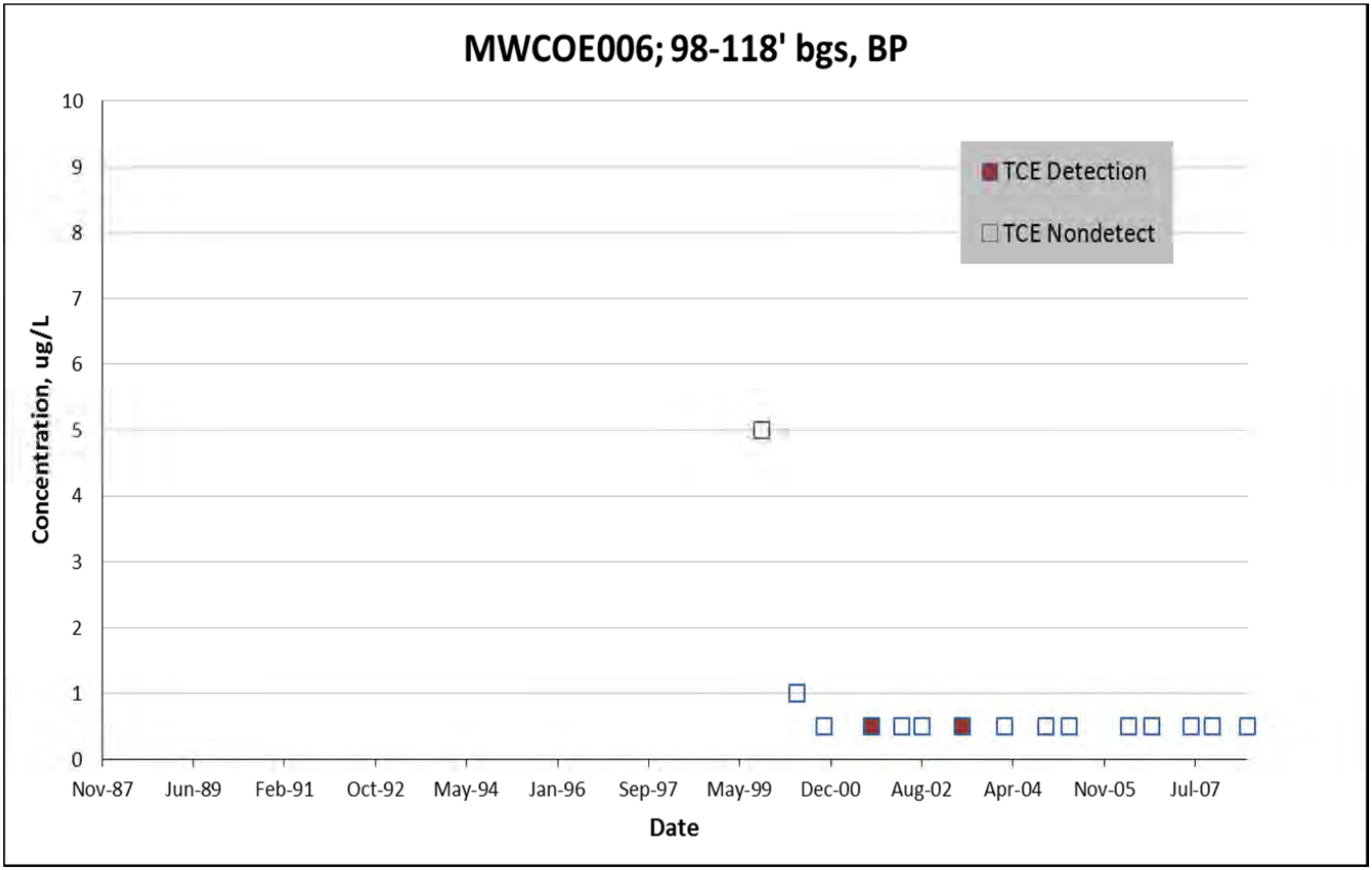

Figure A-58. Time series trend plot of TCE at monitoring well MWCOE006. Sample collected 108 ft below ground surface. Sample type is passive diffusion bag.

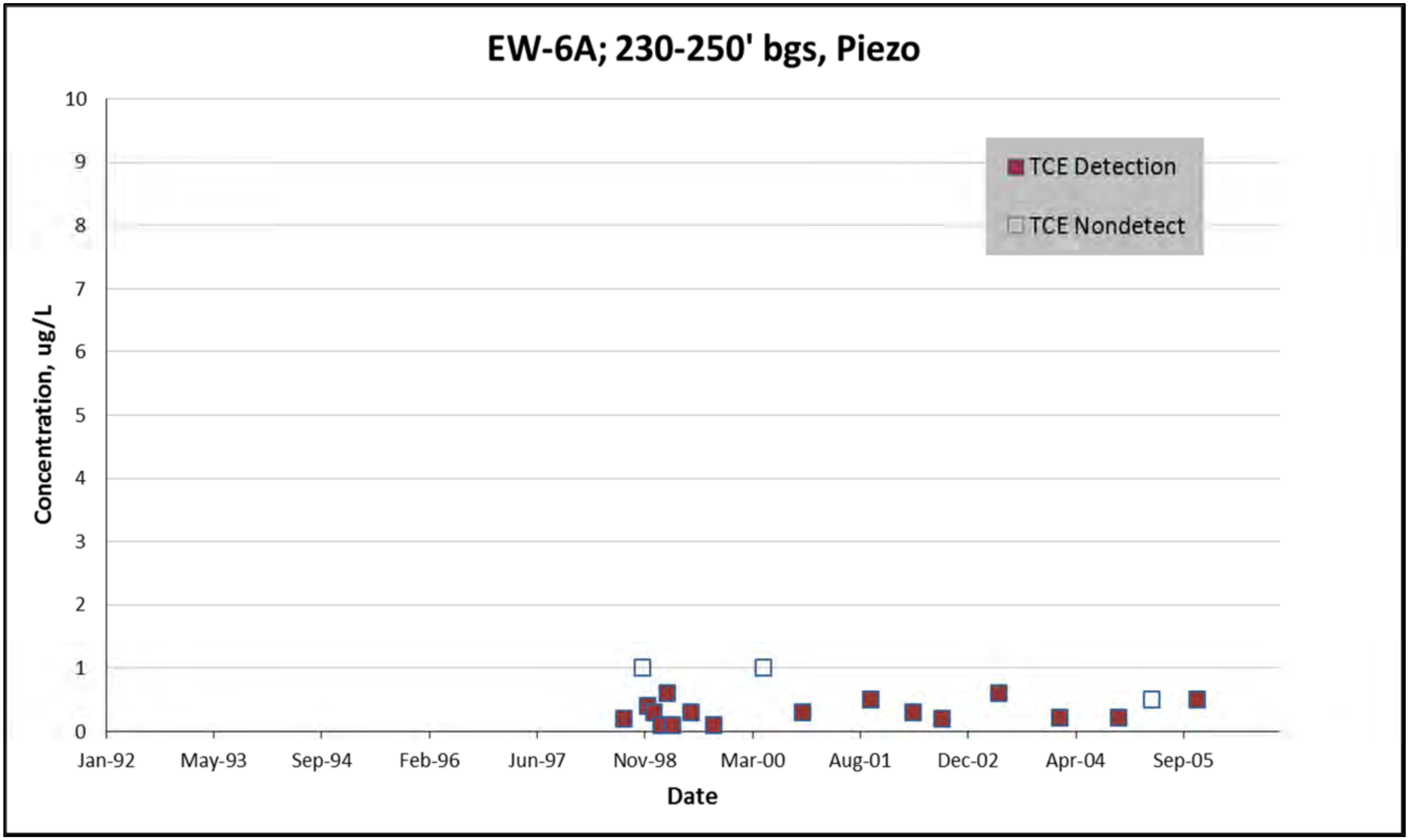

Figure A-59. Time series trend plot of TCE at monitoring well EW-6A. Sample collected 230-250 ft below ground surface. Sample type is piezometer.

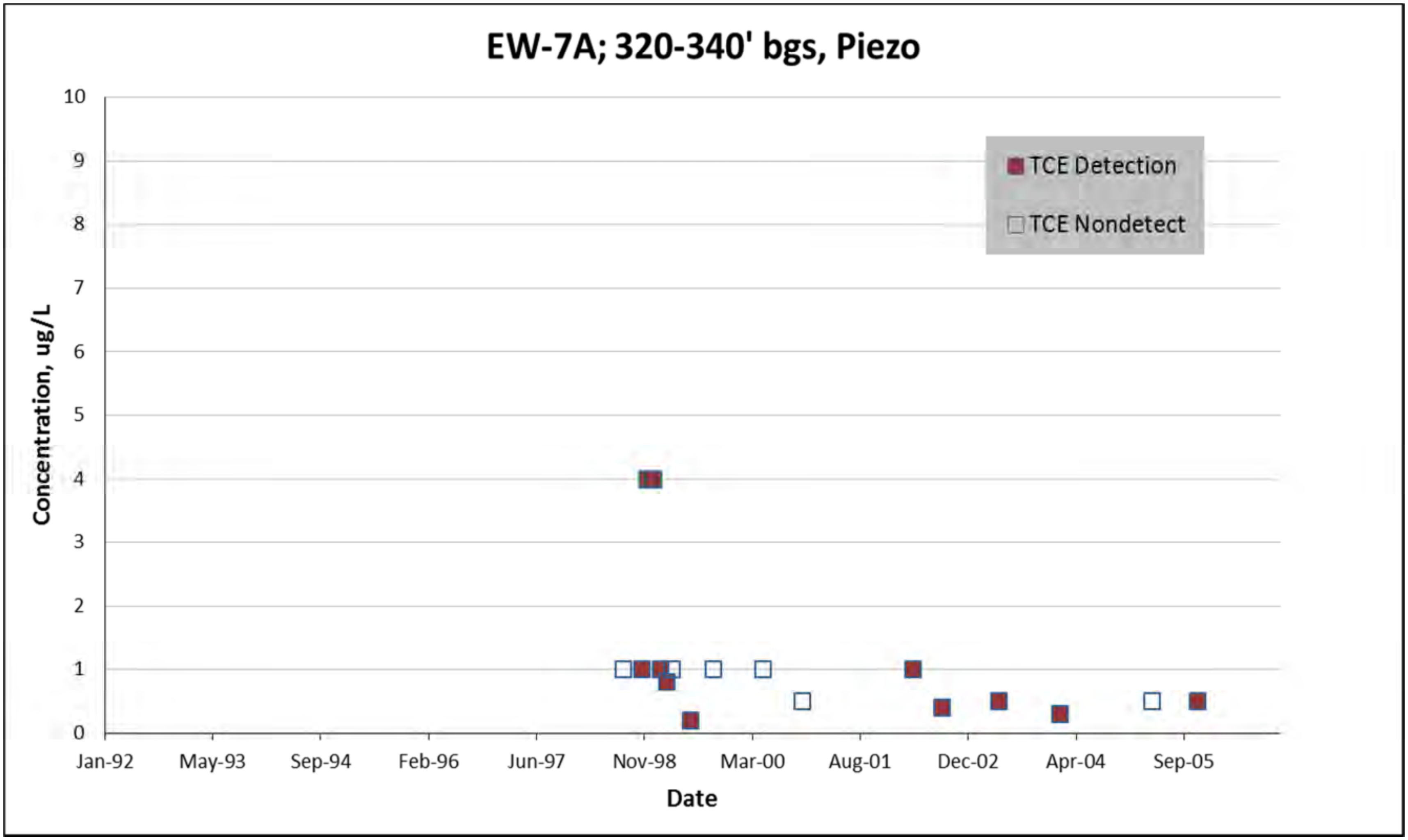

Figure A-60. Time series trend plot of TCE at monitoring well EW-7A. Sample collected 320-340 ft below ground surface. Sample type is piezometer.

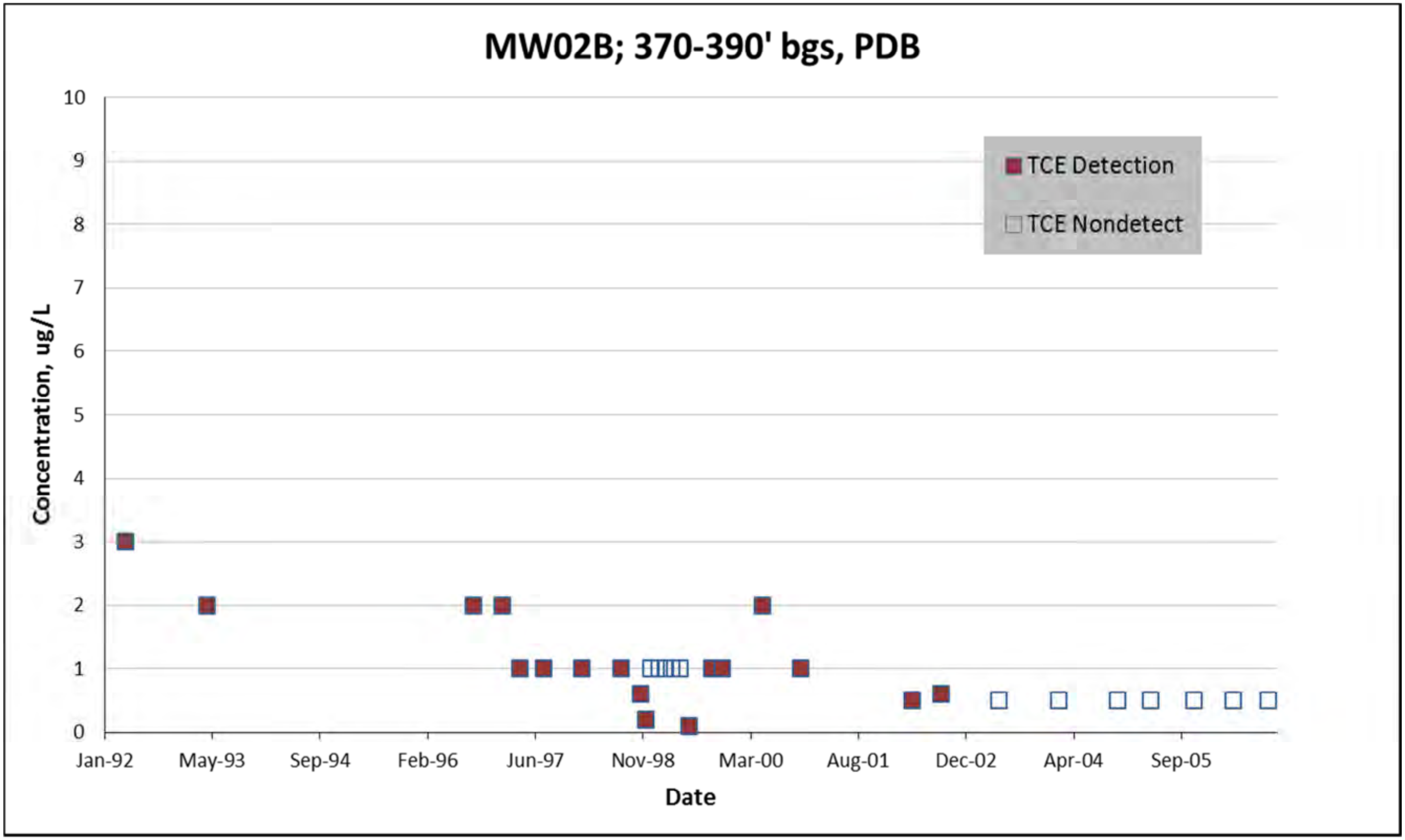

Figure A-61. Time series trend plot of TCE at monitoring well MW02B. Sample collected 380 ft below ground surface. Sample type is passive diffusion bag.

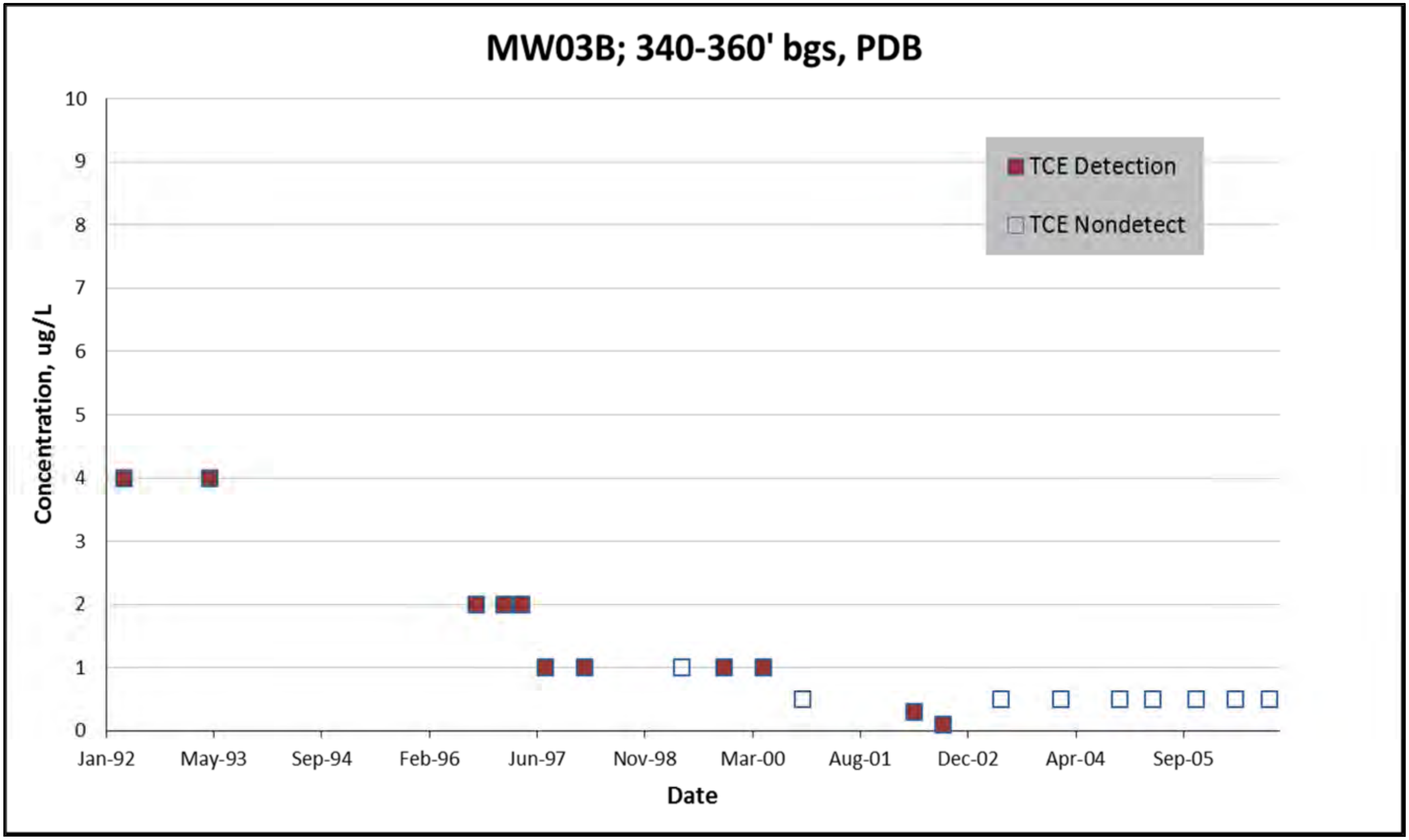

Figure A-62. Time series trend plot of TCE at monitoring well MW03B. Sample collected 350 ft below ground surface. Sample type is passive diffusion bag.

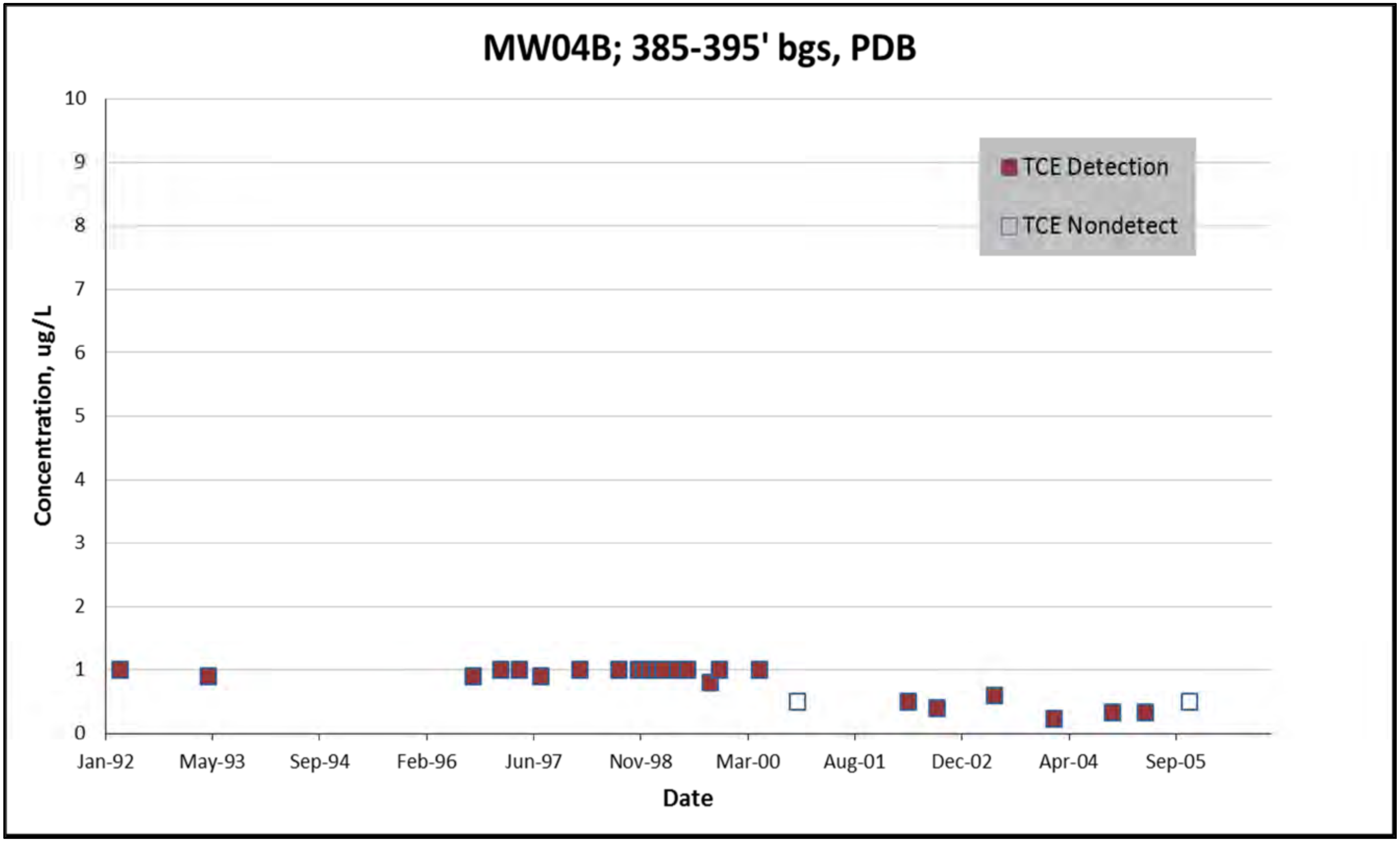

Figure A-63. Time series trend plot of TCE at monitoring well MW04B. Sample collected 390 ft below ground surface. Sample type is passive diffusion bag.

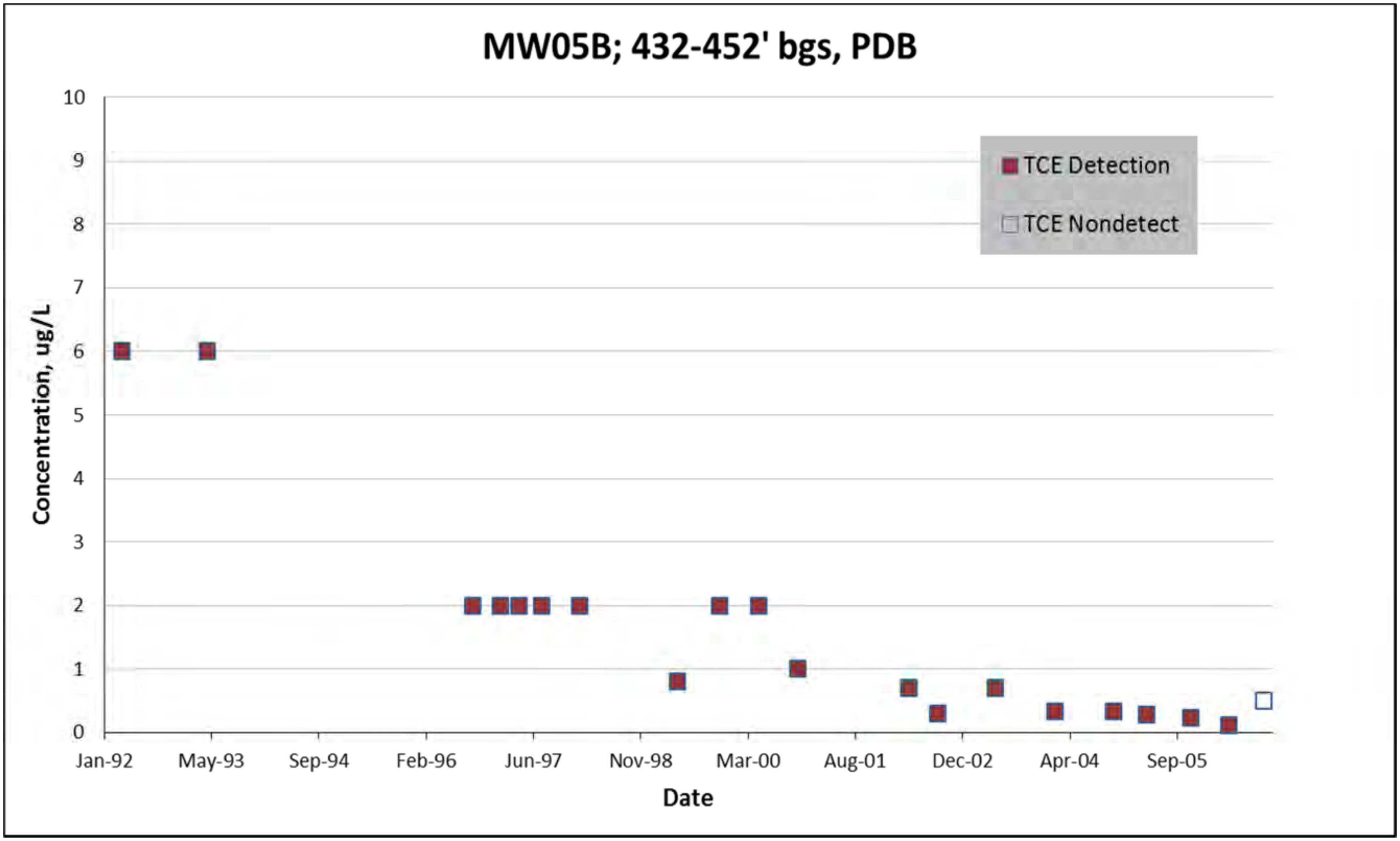

Figure A-64. Time series trend plot of TCE at monitoring well MW05B. Sample collected 442 ft below ground surface. Sample type is passive diffusion bag.

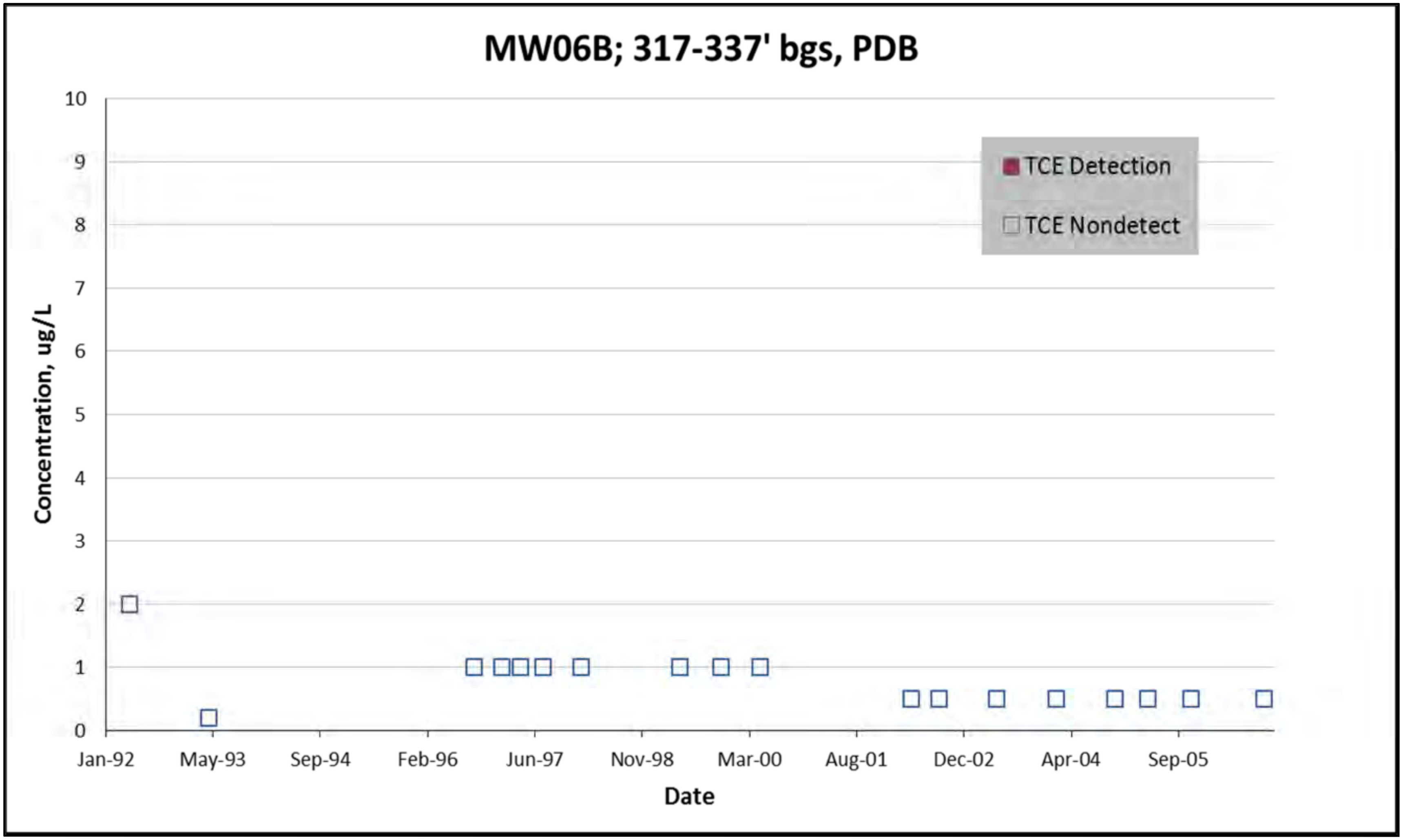

Figure A-65. Time series trend plot of TCE at monitoring well MW06B. Sample collected 327 ft below ground surface. Sample type is passive diffusion bag.

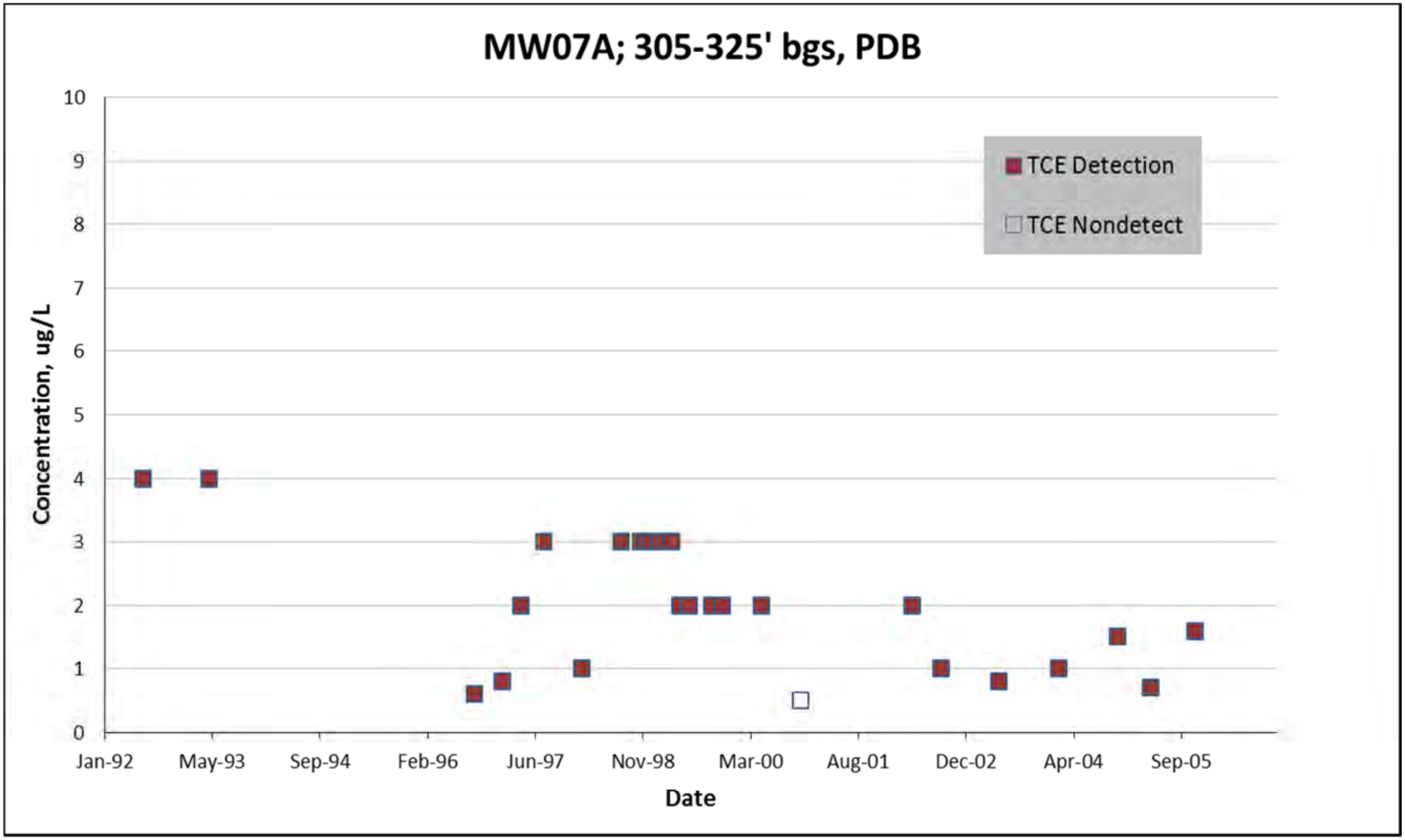

Figure A-66. Time series trend plot of TCE at monitoring well MW07A. Sample collected 315 ft below ground surface. Sample type is passive diffusion bag.

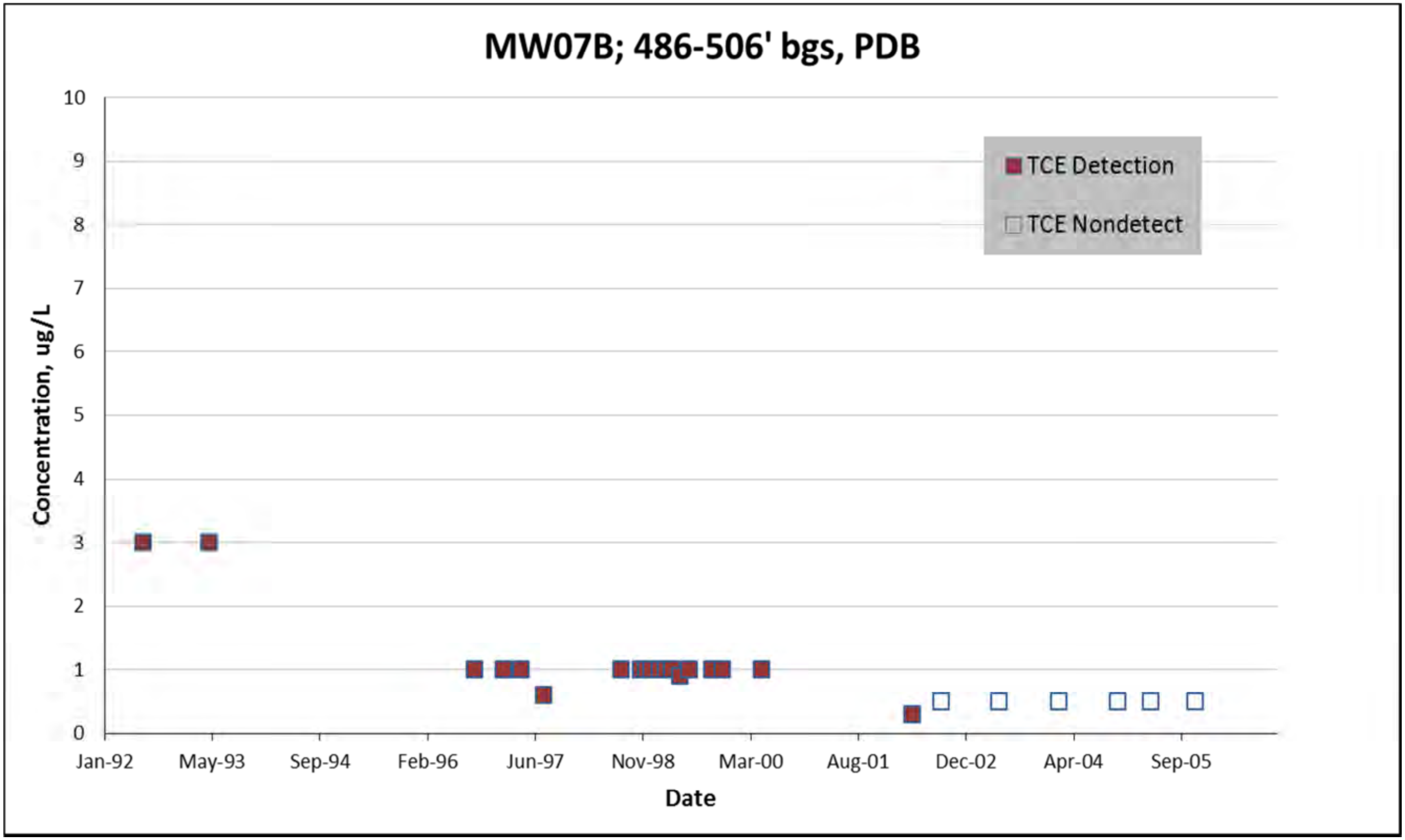

Figure A-67. Time series trend plot of TCE at monitoring well MW07B. Sample collected 496 ft below ground surface. Sample type is passive diffusion bag.

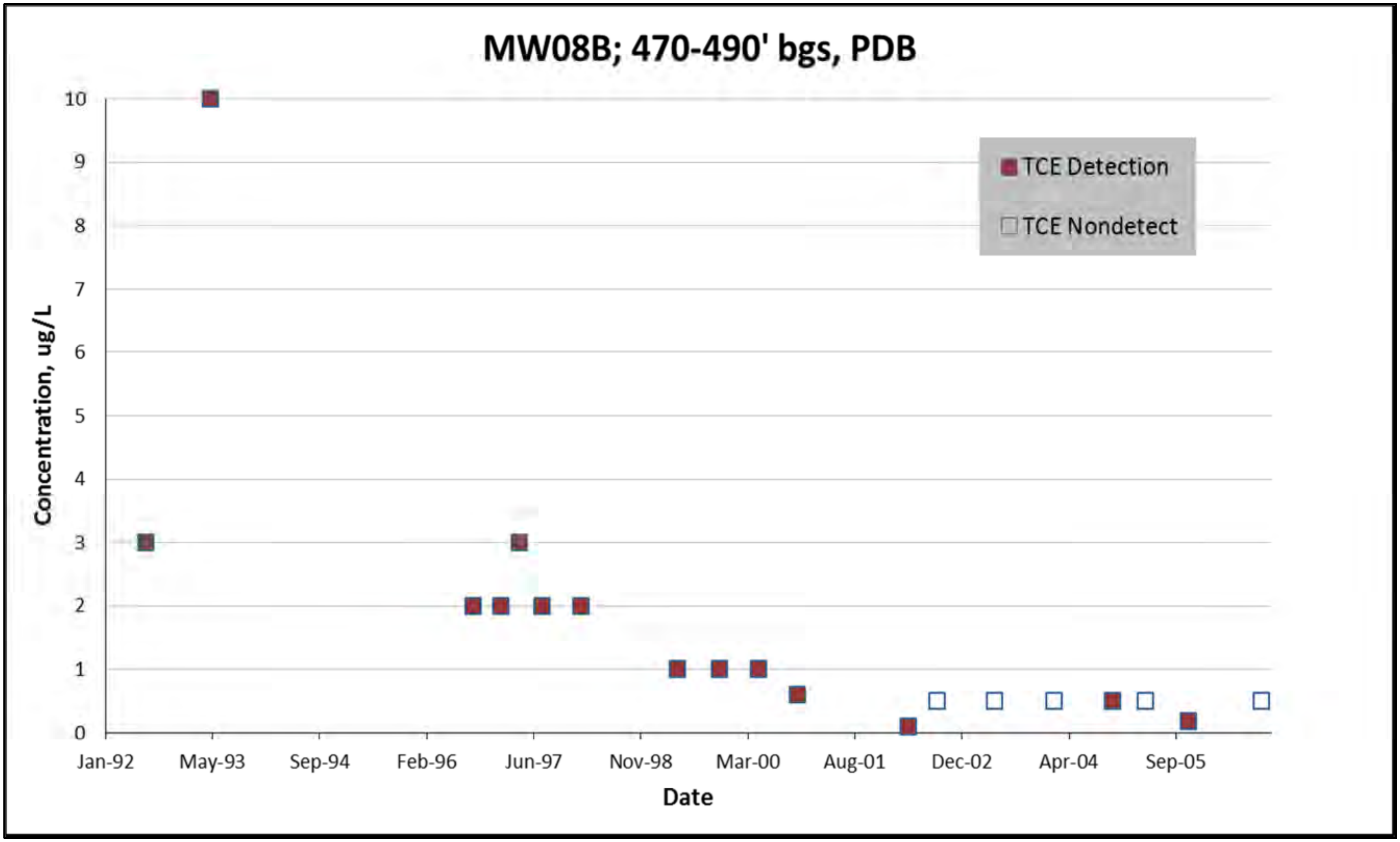

Figure A-68. Time series trend plot of TCE at monitoring well MW08B. Sample collected 480 ft below ground surface. Sample type is passive diffusion bag.

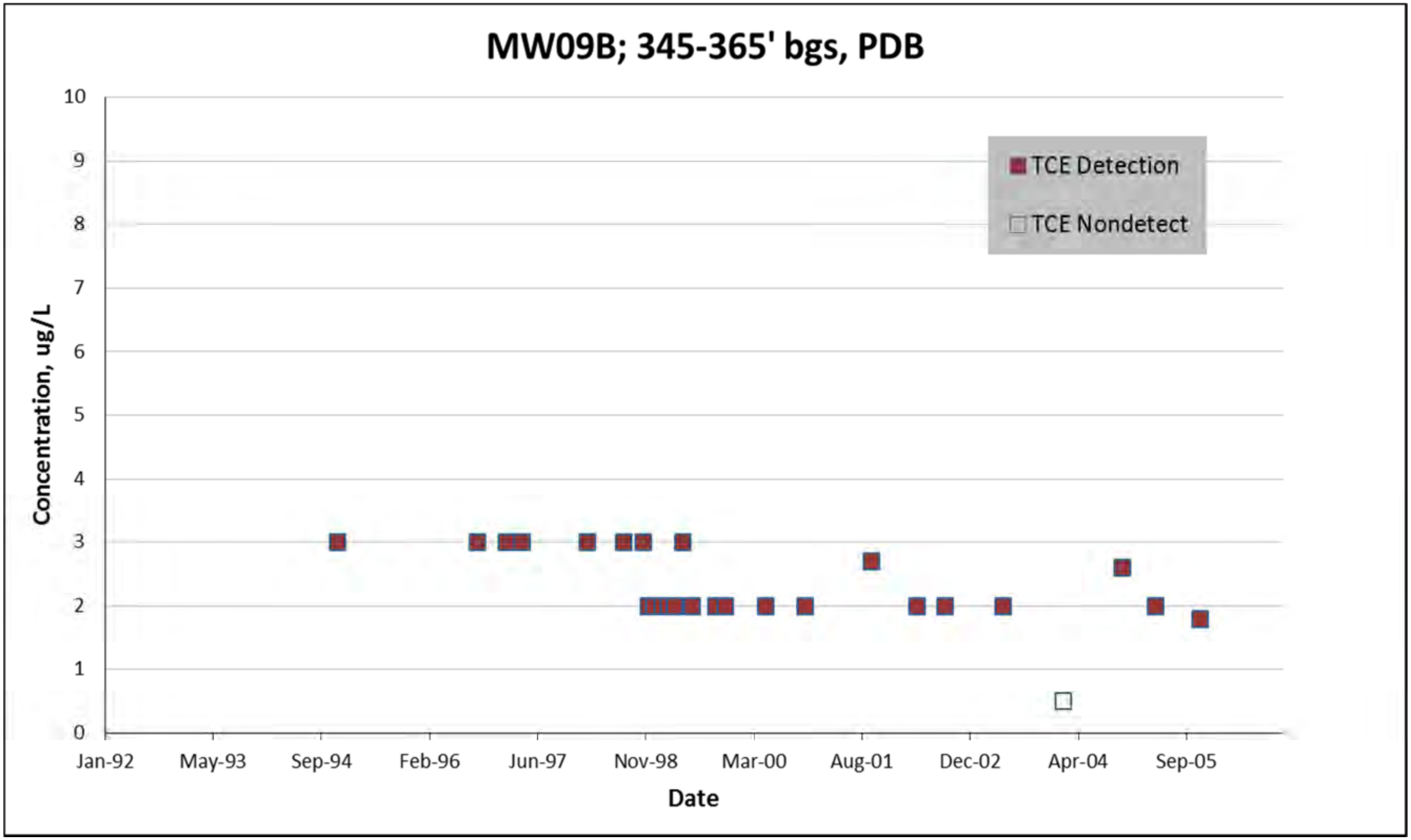

Figure A-69. Time series trend plot of TCE at monitoring well MW09B. Sample collected 355 ft below ground surface. Sample type is passive diffusion bag.

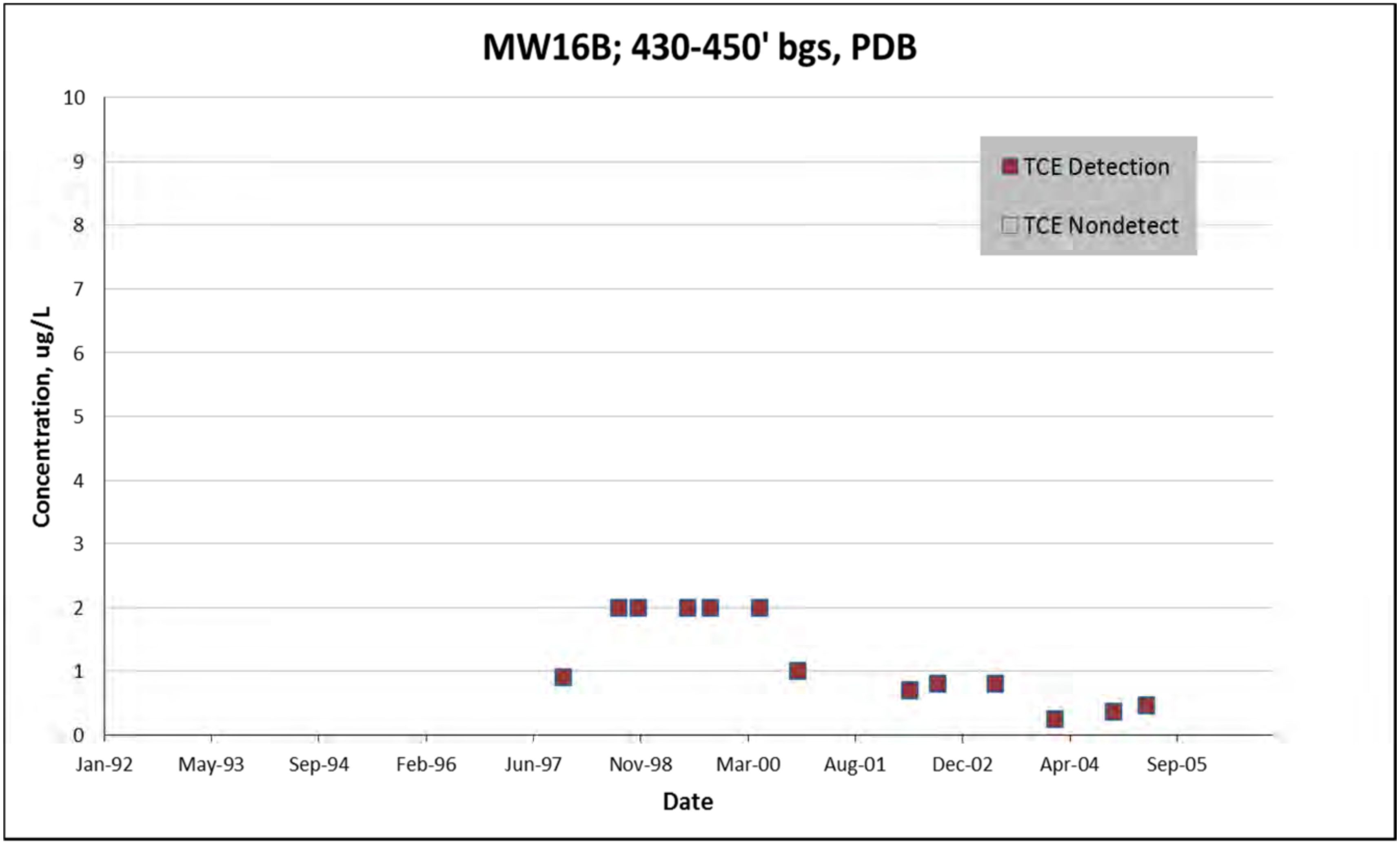

Figure A-70. Time series trend plot of TCE at monitoring well MW16B. Sample collected 440 ft below ground surface. Sample type is passive diffusion bag.

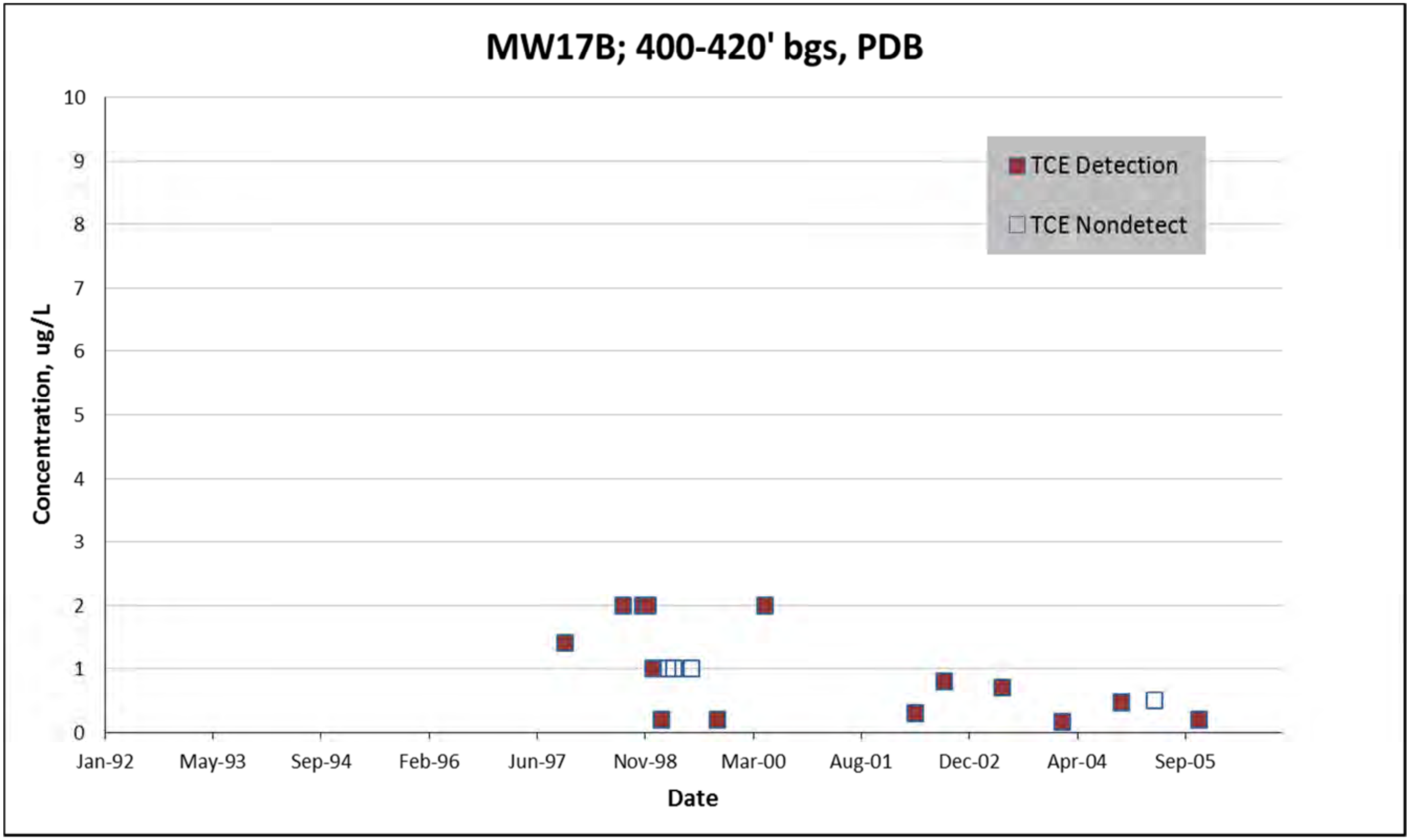

Figure A-71. Time series trend plot of TCE at monitoring well MW17B. Sample collected 410 ft below ground surface. Sample type is passive diffusion bag.

APPENDIX B

4-DIMENSIONAL INTERACTIVE MODEL FILES

(Electronic files only – see Table 7-1 for complete listing of files.)

APPENDIX C

REVISED RISK CALCULATIONS FOR TETRACHLOROETHENE IN DRINKING WATER

Table C-1. Updated Tetrachloroethene (PCE) Calculations for Newmark Site, Reasonable Maximum Exposure (RME) Scenario

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Code Definition	Value	Units	Rationale/ Reference	Chronic Daily Intake (CDI)
Ingestion	Current/Future	Aggregate Resident	Tapwater	EPCgw	Exposure Point Concentration - Groundwater	27	µg/L	URS, 1993	Chronic Daily Intake for Cancer Risk (CDI_C):
	Resident	Age 0 to 26		IFGWadj	Age-Adjusted Tapwater Ingestion Rate	327.95	L/kg	EPA, 2014 (1)	CDI_C (mg/kg-day) =
				IRGW-a	Groundwater Ingestion Rate - Adult	2.5	L/day	EPA, 2014	EPCgw x IFGWadj x CFw
				IRGW-c	Groundwater Ingestion Rate - Child	0.78	L/day	EPA, 2014	ATc
				EDa	Exposure Duration - Adult	20	years	EPA, 2014	
				EDc	Exposure Duration - Child	6	years	EPA, 2014	Chronic Daily Intake for Noncancer Hazard (CDI_{NC}):
				EF	Exposure Frequency	350	days/year	EPA, 2014	CDI_{NC} (mg/kg-day) =
				CFw	Conversion Factor - Water	1.0E-03	mg/µg	--	EPCgw x IRgw x EF x ED x CFw
				BWc	Body Weight - Child	15	kg	EPA, 2014	BW x ATnc
				BWa	Body Weight - Adult	80	kg	EPA, 2014	Where for adult exposure, ED = EDa + EDc, and
				ATnc-c	Averaging Time - Noncarcinogens - Child	2,190	days	EPA, 2014	for child exposure, ED = EDc
				ATnc-a	Averaging Time - Noncarcinogens - Adult	9,490	days	EPA, 2014	
				ATc	Averaging Time - Carcinogens	25,550	days	EPA, 2014	

Updated Risk Calculations	Value	Units	Source
Chronic Daily Intake Cancer (CDI_C)	3.5E-04	mg/kg-day	Calculated
Oral slope factor (SFo) for PCE	5.1E-02	$(mg/kg\text{-}day)^{-1}$	OEHHA, 2007
Cancer risk (CR = CDIC x Sfo)	**1.8E-05**	Unitless	Calculated

Updated Hazard Calculations - Adult	Value	Units	Source
Chronic Daily Intake - Noncancer (CDI_{NC-A})	8.1E-04	mg/kg-day	Calculated
Oral reference dose (RfDo) for PCE	6.0E-03	mg/kg-day	EPA, 2014
Hazard-adult ($HI_A = CDI_{NC-A}$ / RfDo)	**1.3E-01**	Unitless	Calculated

Updated Hazard Calculations - Child	Value	Units	Source
Chronic Daily Intake - Noncancer (CDI_{NC-C})	1.3E-03	mg/kg-day	Calculated
Oral reference dose (RfDo) for PCE	6.0E-03	mg/kg-day	EPA, 2014
Hazard-adult ($HI_C = CDI_{NC-C}$ / RfDo)	**2.2E-01**	Unitless	Calculated

Abbreviations

L/day	Liters per day
L/kg	Liters per kilogram body weight
mg/kg-day	Milligrams per kilogram body weight per day
$(mg/kg\text{-}day)^{-1}$	Risk per milligram per kilogram body weight per day
mg/µg	milligrams per microgram
µg/L	micrograms per liter

Notes:

(1) IFWadj: Consistent with the EPA (2014) RSL User's Guide, an age-adjusted tapwater ingestion rate for aggregate residents calculated as:

IFWadj (L/kg) = (EF_{child} (350 days/year) x ED_{child} (6 years) x IRS_{child} (0.78 L/day) / BW_{child} (15 kg))+(EF_{adult} (350 days/year) x ED_{adult} (20 years) x IRS_{adult} (2.5 L/day) / BW_{adult} (80 kg))

Where: EF = Exposure Frequency (days/year); ED = Exposure Duration (years); IRS = Ingestion Rate of Tap water (L/day); BW = Body Weight (kg) EPA (2014) recommended value for calculating age-adjusted rates.

References:

Office of Environmental Health Hazard Assessment (OEHHA). 2007. OEHHA Toxicity Criteria Database. Accessed June 3, 2014. On-Line Address: http://www.oehha.ca.gov/tcdb/index.asp

U.S. Environmental Protection Agency (EPA). 2014. Regional Screening Levels (Formerly PRGs). May. On-Line Address: http://www.epa.gov/region9/superfund/prg/

URS Consultants, Inc. (URS). 1993. Newmark Project Preliminary Baseline Risk Assessment. Contract No. 68-W9-0054. March 12.

Table C-2. Updated Tetrachloroethene (PCE) Calculations for Newmark Site, Central Tendency Exposure (CTE) Scenario

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Code Definition	Value	Units	Rationale/ Reference	Chronic Daily Intake (CDI)
Ingestion	Current/Future	Aggregate Resident	Tapwater	EPCgw	Exposure Point Concentration - Groundwater	27	µg/L	URS, 1993	Chronic Daily Intake for Cancer Risk (CDI_C):
	Resident	Age 0 to 9		IFGWadj	Age-Adjusted Tapwater Ingestion Rate	142.01	L/kg	EPA, 2014 (1)	CDI_C (mg/kg-day) =
				IRGW-a	Groundwater Ingestion Rate - Adult	2.5	L/day	EPA, 2014	EPCgw x IFGWadj x CFw
				IRGW-c	Groundwater Ingestion Rate - Child	0.78	L/day	EPA, 2014	ATc
				EDa	Exposure Duration - Adult	3	years	EPA, 2004	
				EDc	Exposure Duration - Child	6	years	EPA, 2014	Chronic Daily Intake for Noncancer Hazard (CDI_{NC}):
				EF	Exposure Frequency	350	days/year	EPA, 2014	CDI_{NC} (mg/kg-day) =
				CFw	Conversion Factor - Water	1.0E-03	mg/µg	--	EPCgw x IRgw x EF x ED x CFw
				BWc	Body Weight - Child	15	kg	EPA, 2014	BW x ATnc
				BWa	Body Weight - Adult	80	kg	EPA, 2014	Where for adult exposure, ED = EDa + EDc, and
				ATnc-c	Averaging Time - Noncarcinogens - Child	2,190	days	EPA, 2014	for child exposure, ED = EDc
				ATnc-a	Averaging Time - Noncarcinogens - Adult	3,285	days	EPA, 2014	
				ATc	Averaging Time - Carcinogens	25,550	days	EPA, 2014	

Updated Risk Calculations	Value	Units	Source
Chronic Daily Intake Cancer (CDI_C)	1.5E-04	mg/kg-day	Calculated
Oral slope factor (SFo) for PCE	5.1E-02	$(mg/kg\text{-}day)^{-1}$	OEHHA, 2007
Cancer risk (CR = CDIC x Sfo)	**7.7E-06**	Unitless	Calculated

Updated Hazard Calculations - Adult	Value	Units	Source
Chronic Daily Intake - Noncancer ($CDI_{NC\text{-}A}$)	8.1E-04	mg/kg-day	Calculated
Oral reference dose (RfDo) for PCE	6.0E-03	mg/kg-day	EPA, 2014
Hazard-adult ($HI_A = CDI_{NC\text{-}A}$ / RfDo)	**1.3E-01**	Unitless	Calculated

Updated Hazard Calculations - Child	Value	Units	Source
Chronic Daily Intake - Noncancer ($CDI_{NC\text{-}C}$)	1.3E-03	mg/kg-day	Calculated
Oral reference dose (RfDo) for PCE	6.0E-03	mg/kg-day	EPA, 2014
Hazard-adult ($HI_C = CDI_{NC\text{-}C}$ / RfDo)	**2.2E-01**	Unitless	Calculated

Abbreviations

L/day	Liters per day
L/kg	Liters per kilogram body weight
mg/kg-day	Milligrams per kilogram body weight per day
$(mg/kg\text{-}day)^{-1}$	Risk per milligram per kilogram body weight per day
mg/µg	milligrams per microgram
µg/L	micrograms per liter

Notes:

(1) IFWadj: Consistent with the EPA (2014) RSL User's Guide, an age-adjusted tapwater ingestion rate for aggregate residents calculated as:

IFWadj (L/kg) = (EF_{child} (350 days/year) x ED_{child} (6 years) x IRS_{child} (0.78 L/day) / BW_{child} (15 kg))+(EF_{adult} (350 days/year) x ED_{adult} (3 years) x IRS_{adult} (2.5 L/day) / BW_{adult} (80 kg))

Where: EF = Exposure Frequency (days/year); ED = Exposure Duration (years); IRS = Ingestion Rate of Tap water (L/day); BW = Body Weight (kg) EPA (2014) recommended value for calculating age-adjusted rates.

References:

California Office of Environmental Health Hazard Assessment (OEHHA). 2007. OEHHA Toxicity Criteria Database. Accessed June 3, 2014. On-Line Address: http://www.oehha.ca.gov/tcdb/index.asp

U.S. Environmental Protection Agency (EPA). 2014. Regional Screening Levels (Formerly PRGs). May. On-Line Address: http://www.epa.gov/region9/superfund/prg/

EPA. 2004. Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). Final. Office of Superfund Remediation and Technology Innovation. EPA/540/R/99/005. July.

URS Consultants, Inc. (URS). 1993. Newmark Project Preliminary Baseline Risk Assessment. Contract No. 68-W9-0054. March 12.